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Abstract

The aim of this paper is to assess the causal impact of trade policy distortions on food security. The added value of this work is twofold: i) its use of a non-parametric matching technique with continuous treatment, namely the Generalised Propensity Score (GPS) to address the self selection bias; ii) its analysis of heterogeneity in treatment (by commodities) as well as in outcome (i.e. different dimensions of food security). The results of our estimates clearly show that trade policy distortions are, overall, significantly correlated with the various dimensions of food security analysed. Both discrimination against agriculture and 'excessive' support lead to poor performances in all dimensions of food security (availability, access, utilisation and stability).

Keywords: Food security, International trade, Trade measures, Impact evaluation, GPS

JEL classification: C21, F14, Q17

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1. Introduction

The empirical evidence on agricultural protection/taxation has been summarized by three patterns (Swinnen, 2010): the "development pattern" referring to the positive correlation between agricultural protection and average country incomes; the "anti-trade pattern" referring to the bias in favor of import-competing products; the "relative income pattern" referring to the observation that protection increases when farm incomes fall relative to the rest of the economy. While there is some consensus on the explanation of these patterns in the specialized literature, the debate on the impact of these measures is still animated. Most of the literature is currently focusing on the impact on price level and volatility (Anderson and Nelgen, 2012a,b; Anderson *et al.*, 2013), but less attention has been paid to the impact of these trade restrictions on food security.

This paper contributes to the literature on the relationship between trade policy and food security in two ways. First, it applies a non-parametric matching technique, namely the Generalised Propensity Score (GPS) (Hirano and Imbens, 2004), to control for the likely presence of self-selection bias (i.e. unobserved heterogeneity in treatment propensity that may be related to the variables of outcomes). Second, it controls for treatment heterogeneity (by product) as well as for outcome heterogeneity (dimension of food security) in order to assess the presence of different causal relationships across products and food security dimensions.

The GPS method has been recently applied to various impact evaluation problems lacking experimental conditions: e.g., the impact of labour market programmes (Kluve, 2010; Kluve *et al.*, 2012), regional transfer schemes (Becker *et al.*, 2012), foreign direct investments (Du and Girma, 2009), the EU preferential margins (Magrini *et al.*, 2014), and also the relationship between migration and trade (Egger *et al.*, 2012). To the best of our knowledge ours is the first application of the GPS to assessment of the causal relationship between trade policy distortions and food security.

The outcomes of our estimates show the likely presence of a self-selection bias in the causal relationship between agricultural trade distortions and food security, cross-country and by product. Moreover, we report empirical evidence of a significant impact of agricultural trade distortions on the various dimensions of food security analysed. However, this impact is not consistent with the usual claims by free trade supporters that any policies would do more harm than good. As a matter of fact, a positive level of support for the primary sector is associated with better performances in all the dimensions of food security (food availability, access, utilisation and stability).

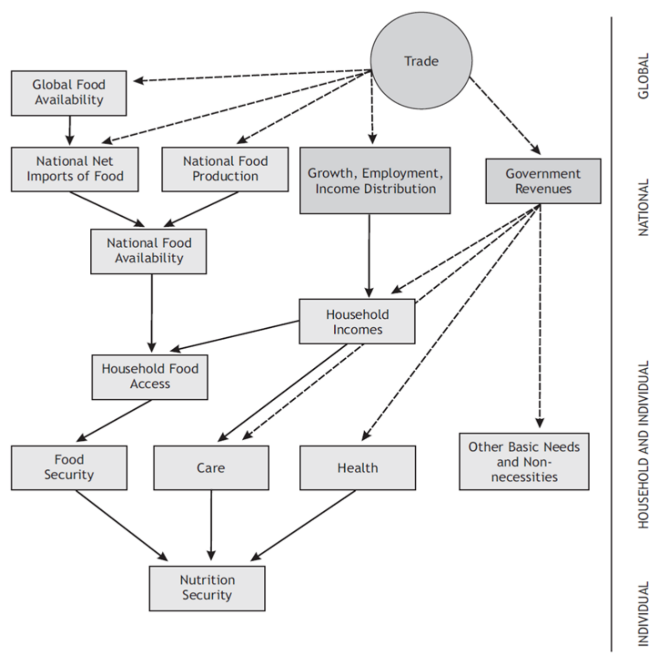
The paper is organised as follows: Section 2 briefly summarises, theoretically and empirically, the links between trade and food security; Section 3 presents the GPS estimator; Section 4 describes variables and data; Section 5 sets out the empirical results; Section 6 concludes.

2. Trade, trade policies and food security: what are the links?

2.1. The conceptual framework

Trade and food security are closely interconnected (Matthews, 2014). International trade affects food security, directly through the impact on food availability, and indirectly through the effects on food accessibility and stability. Smith (1998) and Diaz-Bonilla *et al.* (2002) were among the first to analyse the full set of interactions among these issues and to emphasise the variety of impacts that international trade can have on the determinants of food security. More recently, Huchet Bourdon and Laroche Dupraz (2014) have proposed an extended version of the same conceptual framework. Figure 1 displays the multiple links and interactions between trade and food security from individual to global level.

Figure 1: **Conceptual framework for food security and linkages with trade**



Source: Diaz-Bonilla *et al.* (2002), adapted from Smith (1998).

The first channel through which trade influences food security is via its impact on both global - in the case of the major importer and exporter countries - and national - in the case of the smaller countries - food availability. The second channel is through the impact on both the level and the stability of the rate of growth, as well as on employment, income distribution, and poverty. A third channel is *via* trade policy through government revenues, directly (as the collection of trade taxes) and indirectly (through their impact on the rate and variability of growth)(Diaz-Bonilla and Ron, 2010) . Recently, Matthews (2014) underlines the role that trade rules, and specifically an open and predictable trading system, play in promoting global food security governance by making the international food system more efficient and more responsive to sudden shocks.

While these multiple channels have heterogeneous impacts on the various components of the standard definition of food security, it is undeniable that trade and trade policies influence the profits of food producers and the food costs for consumers, mainly because of their effect (both on levels and volatility) on world and domestic food prices. High food prices can impact positively on food availability, improving food production and access to it by increasing producers' incomes. At the same time, they can reduce economic access to food because it becomes more costly on the consumption side (Diaz-Bonilla and Ron, 2010). Also price volatility can affect food security via its impact on household welfare on both the production and consumer sides. Producers react to extreme/unpredictable price volatility, by under-investing or investing in "wrong projects" (Caballero, 1991; Bertola and Caballero, 1994; Aizenman and Marion, 1994); consumers do so by deviating from a smooth path of consumption (Loayza *et al.*, 2007; Montalbano, 2011; Anania, 2013). Furthermore, price volatility also interacts with price level in affecting welfare: the higher the price, the stronger the welfare consequences of volatility for consumers, while the contrary is the case for producers (HLPE, 2011).

Because of the pervasive role of prices in food security, pro-cyclical trade policies are often applied to insulate domestic markets from international price turmoil. Although numerous justifications for such trade measures are possible, food security has been claimed to be the dominant reason for resorting to trade measures in the recent food price crises (Rutten *et al.*, 2013).

The set of trade policy measures adopted to insulate price rising varies in many respects. They include both export restrictions adoption and import restrictions relaxation. To be noted is that an export tax (or import subsidy) is the equivalent of a consumer subsidy and a producer tax, while an import tax (or export subsidy) is the equivalent of a consumer tax and a producer subsidy. These measures differ in terms of their transparency and the administrative burden involved in their implementation, and they have different distributional effects. The extent of the impact of these policies on the world market depends on a number of factors, including the size of the country adopting them; the characteristics of world demand for and supply of the specific product; whether or not the increase in the international price is product specific; the volume of the product traded internationally relative to world production (Anania, 2013). Explicit consideration of all the transmission channels and/or all the heterogeneous factors that may impact on the relationship between trade policy and food security is beyond the scope of our empirical exercise. A workable method with which to address properly the identification issue between changes in trade policy at the border and changes in the observable dimension of food security at the national level is to apply appropriate non-parametric methods to control for self-selection bias (i.e. controlling for unobserved heterogeneity in treatment propensity related to outcome performances) and heterogeneity in both treatment and outcome.

2.2. Are these policy measures effective?

The bulk of the empirical evidence shows that countries which have imposed trade measures are effective in making domestic prices rise significantly less than those in countries which have not intervened (see, among others, Abbott (2011); Dawe and Timmer (2012); Demeke *et al.* (2009); Jones and Kwiecinski (2010); McCalla (2009). Abbott (2011) and Jones and Kwiecinski (2010) - analysing maize, rice, soy-beans and wheat price changes in a wide set of countries - conclude that most of the countries that have restricted exports have experienced significantly lower price increases compared with those that have not. From a geographic perspective, Asian rice exporters have achieved greater price stabilisation than have export restricting countries in Latin America and Eastern Europe (Abbott, 2011; Demeke *et al.*, 2009). Dawe and Timmer (2012) underline how during the world rice crisis of 2008, China, India and Indonesia successfully insulated their domestic rice economies from the turmoil on world markets. Their analysis also shows how the impact on the volumes exported varies significantly across the countries that intervened to restrict them. Jones and Kwiecinski (2010) find that China, India, and Ukraine register significant reductions of their wheat exports; the same applies to China and Ukraine for maize, and to China and India for rice.

In the case of small countries, trade measures are bound to reduce national economic welfare in a first best setting. If the country is large, its policy intervention will affect not only the domestic price but also the international one, leading to further distortive effects. Rutten *et al.* (2013), Anderson *et al.* (2013), and Anderson and Nelgen (2012c) highlight that if many countries adopt the same measures, these measures may prove to be completely ineffective also because the impact of price insulation depends on both the actions taken by the single country and the collective impact of interventions by all other countries. They emphasise that trade insulating measures push world food prices to even higher levels and, with a domino effect, drive more countries to follow, thereby perpetuating high food prices, reducing both the impact of each country's initial action on its domestic price and the ability of the policy reaction by each country to yield the desired effect (because their policies will partially offset each other), and exacerbating food insecurity around the world (Martin and Anderson, 2011, 2012; Mitra and Josling, 2009). In their analysis of the wheat market, Rutten *et al.* (2013) find that major net exporters are generally better off when implementing export taxes for food security purposes. Large exporting countries export price instability causing world food prices to rise further. Net importing countries lose out, and they have limited room to reduce tariffs or subsidise imports. When wheat trade is liberalised, it mitigates rising prices and contributes to food security, but to the detriment of production in other countries (mainly those of Africa and Asia), making them more dependent on and vulnerable to future changes in the world market.

According to Anderson and Nelgen (2012c), domestic market insulation using trade measures is also inefficient and possibly inequitable. The traditional national government trade policy reactions to food price spikes would also be undesirable because, collectively, they are not very effective in stabilizing domestic prices, not least because they add to international price volatility by reducing the role that trade between nations can play in bringing stability to the world's food markets. Some scholars (Martin and Anderson, 2011; Anderson and Nelgen, 2012c,a; Rutten *et al.*, 2013; Anderson *et al.*, 2013; Timmer, 2008; Gotz *et al.*, 2013) go so far as to say that trade policies adopted by countries in order to stem the recent price spikes have even amplified both price spikes and volatility and exacerbated the already negative consequences of high prices for the food security of the population in the developing countries. Anderson *et al.* (2013) estimate the extent to which the observed insulating actions of more than 100 countries in the period 2006-2008 affected the international and domestic food prices of four food items: rice, wheat, maize and edible oils. They find that the adoption of price insulation caused substantial increases in international prices that completely offset the benefits, and that the actual poverty-reducing impact of insulation is much less than expected. Furthermore, they find that developing countries as a group insulated more than developed countries, with the consequence that parts of the price increases were "exported" to developed countries. Martin and Anderson (2012) examine the role of trade policies (particularly export and import restrictions) as stabilization policies in the agricultural market. They state that the use of these measures by all countries is ineffective in stabilizing the domestic prices of the key staple foods of rice and wheat, while magnifying the international price instability associated with exogenous shocks to food markets. Their analysis shows that in the 2006-08 surge, insulating policies affecting the market for rice explained 45 percent of the increase in the international rice price, while almost 30 percent of the observed change in the international price of wheat during 2006-08 can be explained by the changes in border protection rates. Mitra and Josling (2009) emphasize the negative effects caused by the adoption of export restrictions as a response to the dramatic increase in commodity prices in 2007-08. They state that these measures led to further price increases by placing limits on global supply and undermining the level of buyer confidence with a consequent harmful impact on domestic food security. Gotz *et al.* (2013) analyse the impact of export restrictions on price volatility in the Ukrainian wheat market during the commodity price peaks 2007-08 and 2010-11. They find that export controls did not significantly reduce price volatility on the domestic wheat market. On the contrary, those policy measures substantially increased market uncertainty, which led to pronounced additional price volatility in the market.

This brief literature review on the efficacy of trade policy distortions on food security highlights that the relationship is ambiguous and that thorough analysis of the exact channels of transmission is a complex undertaking. A workable solution is to investigate empirically the overall net impact of trade insulating policies on food security. This requires appropriate methods with which to analyse the causal effect of different treatment intensity among observations that can be considered as similar conditional on a set of common characteristics.

3. Methodology: the GPS estimator

The GPS estimator - originally proposed by Hirano and Imbens (2004) and Imai and van Dyk (2004) - is a generalisation of the binary treatment propensity score. It is a non-parametric method to correct for selection bias in a setting with a continuous treatment by comparing units that are similar in terms of their observable determinants of "treatment intensity" within the treatment group. Hence, it does not require control groups.

Let us use index $i = 1, ..., N$ to refer to a random sample of units. The GPS method is based on the following assumptions: for each i we postulate the existence of a set of potential outcomes, $Y_i(t)$, for $t \in$ where T (the treatment) is a continuous interval of real numbers, referred to as the *unit-level* dose-response function (DRF). We are interested in estimating the *average* DRF, $D(t)$, across all units i that illustrates the expected value of the outcome variable conditional on continuous treatment as follows:

$$D(t) = E[Yi(t)] \tag{1}$$

Estimation of the $D(t)$ uses information on three sets of data: a vector of covariates X_i, a "treatment" received, T_i and a potential outcome, $Y_i = Y_i(T_i)$. Following Hirano and Imbens (2004) we assume that: $Y_i(t)_{t\in}$, T_i and X_i are defined on a common probability space; T_i is continuously distributed with respect to a Lebesgue measure on T; $Y_i = Y_i(T_i)$ is a well defined random variable.

Following Hirano and Imbens (2004), we define GPS as:

$$R = r(t, X) \tag{2}$$

where R is the propensity score, i.e. the conditional probability of receiving a specific level of treatment given the covariates, and which is estimated via the following standard normal model:

$$\widehat{R}_i = \frac{1}{\sqrt{2\pi\widehat{\sigma}^2}} exp\left[-\frac{1}{2\widehat{\sigma}^2}(t_i - \widehat{\beta}_0 - X\widehat{\beta}_1)^2\right] \tag{3}$$

where $\widehat{\beta}_0$ and $\widehat{\beta}_1$ are the parameters to be estimated. The main purpose of estimating GPS is to create covariate balancing. However, the validity of R as a measure of similarity or dissimilarity across observations depends crucially on the validity of a set of assumptions which are standard in the impact evaluation literature. Firstly, the randomness of the treatment, i.e. the assumption of "unconfoundedness" or "ignorability of the treatment". Which means in this case avoiding the likely selection bias between food insecurity (the outcome) and trade policy distortions (the treatment) due to the fact that the net food importer and exporter developing countries are more likely to adopt agricultural trade distortions during the food crisis. Imbens (2000) shows that if the treatment assignment is weakly unconfounded given the observed covariates, then the treatment assignment is weakly unconfounded given the GPS. In other words, the GPS has the following property:

$$X \perp 1\{T = t\} | r(t, X)(4)$$

The GPS removes the bias associated with differences in covariates in three steps. In the first step, the GPS is estimated, and its balancing property is checked. If balancing holds, observations within GPS strata can be considered as identical in terms of their observable characteristics, independently of their actual level of treatment.[1] The validity of the balancing property should be coupled with the SUTVA (Stable Unit Treatment Value Assumption) condition. This assumption has two parts: the "unique treatment assumption" (i.e. the treatment is identical for each treated observation) and the "non- interference assumption", i.e. observation on one unit should be unaffected by the particular assignment of treatments to the other units. Notwithstanding the presence of some degree of heterogeneity in trade policy coverage, here we use a standardized measure that prevents violation of the unique treatment assumption. This measure synthesizes the

[1]Please note that as long as sufficient covariate balance is achieved, the exact procedure for estimating the GPS is of secondary importance (Kluve *et al.*, 2012).

actual impact of the set of the standard trade policy measures, both tariff and non-tariff, that characterizes policy distortions across countries in a uniform manner and in a comparative setting.

At the same time, in order to avoid the likely risk of interference and spillovers due to treatments assigned to the main exporter and importer countries, we run the empirical analysis removing from the sample the countries reporting the higher quotas in terms of trade value at the global level in the agricultural sector during the period 1990-2010, using Direction of Trade Statistics (DOTS). In particular, we remove both the top 10 exporters and the top 10 importers.[2]

Then, two additional steps are needed to eliminate the bias associated with differences on the covariates (see Hirano and Imbens (2004) for a proof). The first one is estimation of the conditional expectation of the outcome Y as a function of two scalar, the treatment level T and the GPS R as follows:

$$\beta(t, r) = E[Y|T = t, R = r] = \psi[t, r; \alpha] \tag{5}$$

where α are the parameters to be estimated. This is generally assumed to be a flexible parametric specification between the three variables at different order of the polynomial terms. The statistical significance of the GPS parameters is a sign that selection bias is actually an issue. Interaction terms between the treatment level and the GPS are usually applied to control for the marginal impact of the treatment relative to the GPS.

The final step is to compute the average dose-response function (DRF) of the outcome (i.e. the different dimensions of food security) by averaging the conditional expectation over the GPS at any different level of treatment, as follows:

$$D(t) = E[\beta(t, r(t, X))] \tag{6}$$

Furthermore, we can calculate the varying marginal effects of the treatment by estimating the treatment effect function (TEF), which is the first derivative of the corresponding DRF as follows:

$$\theta(D) = D(t + \delta) - D(t) \tag{7}$$

[2]Note that 8 countries out of 10 are both main exporters and importers, namely the United States, Germany, France, Italy, Spain, the Netherlands, Belgium and China. Brazil and Canada are the other two main exporters, while Japan and the UK are the other two main importers. We also performed the same exercise removing all the EU member countries, but the final results (available upon request) did not change significantly. Unfortunately, the same sample selection could not be applied to the sensitivity analyses carried out for rice and wheat because of the limited number of observations that would be available after the correction.

4. Variables and data

In our exercise we use index i to indicate countries and assume the unit-level dose-response of potential outcomes of food security, Y_{it} as a function of the treatment t, where t is the annual Nominal Rates of Assistance to producers (NRA). To this end, three different sets of data are used: i) the NRA (i.e. the treatment, T_i) derived from the World Bank dataset ("Updated National and Global Estimates of Distortions to Agricultural Incentives, 1955 to 2010") by Anderson and Nelgen (2012b); ii) the observable characteristics able to explain the probability of reaching a specific level of NRA (i.e. the covariates, X_i); iii) the outcome in terms of the various dimensions of food security ($Y(t)$). Table A.2 in the Appendix synthesises the data applied in our empirical exercise, while Table A.3 provides the mean, minimum, maximum and standard deviation for the covariates.

4.1. The treatment: the Nominal Rates of Assistance

The Anderson and Nelgen (2012c) World Bank dataset provides the annual values of a set of standardised measures of policy-related agricultural trade distortions for a total of 82 countries (that together account for over 90% of global agricultural output) and 70 products for the overall period 1955-2011. It contains aggregate and by product NRA measures defined as the percentage by which government policies directly raise (or lower) the gross return to producers of a product above the world price. The focus is on border and domestic measures that are due exclusively to governments' actions, and as such can be altered by a political decision and have an immediate effect on consumer choices, producer resource allocation, and net farm incomes (Anderson and Valenzuela, 2008). In practice, there are divergences among farmer, processor and wholesaler, consumer, and border prices for reasons other than policies. These costly value chain activities need to be explicitly recognized and netted out when using comparisons of domestic and border prices to derive estimates of government policy-induced distortions. More specifically, NRA is computed as follows:

$$NRA = [E.P(1 + d) - E.P]/E.P$$

where E is the exchange rate, d is a distortion due to government interventions and P is the foreign price of an identical product in the international market (Anderson, 2006). Positive values of NRA denote a rise in domestic producers' gross return (the distorted price is higher than the undistorted equivalent because of the presence of an output subsidy and/or a consumption tax, e.g. a tariff), while negative values denote a lower gross return for domestic producers (the producers receive less than the price would be for a like product in the absence of government interventions, e.g., an export tax). To be noted is that NRA tends to be higher for import-competing producers than for net exporters of a specific product (Anderson, 2013), confirming the "anti-trade pattern" acknowledged in the literature (Swinnen, 2010).

Two main hurdles, conversion and aggregation problems, need to be overcome. On the one hand, given the continuing and possibly growing importance of agricultural NTBs, protection can take many different forms - tariffs, quotas, anti-dumping duties, technical regulations - so that we need to convert the different instruments into a common metric (Cipollina and Salvatici, 2008). The WB database deals adequately with this issue by undertaking careful domestic-to-international price comparisons for the key farm products for a large set of OECD and developing countries, thereby capturing also the domestic price effects of NTBs (Lloyd *et al.*, 2010). This was computed by comparing domestic and border prices of like products (at similar points in the value chain) for each of the farm industries covered, drawing on national statistical sources supplemented - where necessary - by producer prices and unit values of exports and imports from FAO (2011).

On the other hand, trade policy is set at a very detailed level, and this information needs to be summarized into one aggregate and economically meaningful measure. The World Bank's database solves these problems as follows: "the weighted average NRA for covered primary agriculture can be generated by multiplying each primary industry's value share of production (valued at the farmgate equivalent undistorted prices) by its corresponding NRA and adding across industries. The overall sectoral rate, denoted as $NRAag$, can be obtained by adding the actual or assumed information for the non-covered commodities and, where it exists, the aggregate value of non-product-specific assistance to agriculture" (Anderson and Nelgen (2012c) p. 577).

4.2. The covariates

In regard to the set of covariates, we selected the following set of pre-treatment variables: the log of real per capita GDP, its squared and cubic power (to control for non linearities in the anti-trade behaviour of the most advanced economies and to facilitate the balancing property as suggested by Dehejia and Wahba (1999) and Dehejia (2005)); the log of total population (to control for country size); the log of per capita arable land (to control for the relative agricultural comparative advantage); the food production index (to control for the actual productivity of the agricultural sector); the share of the value of food imports over total exports and its squared power (to control for the level of country food dependence on abroad); the absolute percentage (positive and negative) deviations from the trend in food international prices (to control for the presence of asymmetric policy responses to sizeable changes in price levels); a measure of international food price volatility (to control also for the second moment of the relationship between international prices' dynamics and trade distortions). Furthermore, we add a set of dummies to control for net exporter status and the recent food crisis (2007/2008), and a set of unobservable factors for the groups of countries belonging to the same regional area - African developing countries (base); Asian developing countries; European transition economies; Latin American developing countries and high income countries. While other determinants could be considered in our matching exercise, to be noted is that, as argued by Bryson *et al.* (2002), there is always a trade-off between increasing the explanatory power due to the use of additional covariates and the risk of over-parametrized models that could, in turn, exacerbate the support problem and increase the variance of the propensity score estimates.

4.3. The outcome: the dimensions of food security

Last but not least, we should deal with the difficult task of retrieving a suitable and workable measure of outcomes in terms of food security, which infact covers a complex set of concepts and dynamics. One of the most popular definitions of food security emphasizes its multidimensionality, describing food security as the condition that "exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (CFS, 2009). Since no single indicator is able to capture all the identified dimensions that comprise the problem, there has been a proliferation of proposals for food security indicators.

We decide not to use a composite indicator of food security, but rather to differentiate food security indicators according to the working concept based on the standard four dimensions (CFS, 2009), namely availability, access, utilization and stability. Availability is a measure of the amount of food physically available in a population during a certain period of time (most likely related to production and market availability) (Cafiero, 2013). The accessibility dimension embraces Sen's framework of the capability approach emphasising that food availability does not guarantee that everyone is free from hunger (Sen, 1981). The third dimension - utilization - is a measure of a population's ability to obtain sufficient nutritional intake and nutrition absorption during a given period. The last dimension - stability - refers to the risk component of the above three (such as natural events, man-made shocks, malfunctioning international markets, etc.) (Pangaribowo *et al.*, 2013). As underlined by Cafiero (2013) and Pangaribowo *et al.* (2013), each dimension can be represented by a specific set of variables and indicators. Taking actual data availability into account, we selected the following: supply of food commodities in kilocalories per person per year (for food availability); depth of the food deficit (for food access); infant mortality (for food utilisation) and per capita food supply variability (for stability) (see Table A.2 in the Appendix) for additional details and sources' availability.

5. Empirical results

We carried out the empirical exercise for each dimension of food security. Along with the aggregate case, we also report sensitivity estimates for the two main exporting crops, wheat and rice. Because of data constraints in food security measures, we are forced to limit our dataset to the sub-period 1990-2010. Furthermore, to avoid possible sources of bias we omitted from the aggregate analysis the main importer and exporter countries (see section 3).[3] Hence, our sample of countries reduces to 64 countries (see Table A.1 in the Appendix for the list of countries included in our empirical exercise). Among the estimated trade distortion measures, we use $NRAag$ for the aggregate exercise and NRA by commodity for the product level analysis (see Table A.2 in the Appendix). As in Anderson and Nelgen (2012c) and Anderson and Nelgen (2012a), NRA data have been converted to a nominal assistance coefficient ($NAC = 1 + NRA$) in order to transform NRAs negative values (i.e. when producers receive less than the price at the border in the absence of government intervention) into NAC values between zero and one (one becomes the threshold between a positive and negative NRA). Movements of domestic prices above the world ones, for instance through import taxes or export subsidies, lead to increases in NCA above 1, while trade liberalization is signaled by reductions in the NCA. However, when policies are targeted on domestic producers, as in the case of import subsidies or export taxes, the dynamics are reversed. In these cases, world prices are higher than domestic ones: NCAs are lower than 1 and they would increase due to trade liberalization. The bottom line is that care should be taken in interpreting the NCA dynamics when different types of border policies are taken into account. NAC observations before the 5 percentile and after the 95 percentile have been removed from the sample in order to clean our dataset from potential outliers. Finally, a zero-skewness log transformation has been applied to normalize the NAC distribution.

5.1. Regression outcomes

We first apply a regression type analysis to control for the possibility of reverse causality between food security and trade policy distortions. Specifically, we estimate the relation between the food availability dimension and NRA by using the following panel regression:

$$f_{id} = \alpha + \beta_1 t_{id} + \beta_2 x_{id} + \epsilon_{id} \quad (8)$$

[3] It is worth noting that including them did not significantly change the empirical outcomes and the corresponding DRF. Similar outcomes were obtained on omitting the EU member countries from the analysis. The results are available from the authors upon request.

where f is our proxy for food availability (food supply in kcal/capita/day); t is NRA; x is a bundle of observable country level covariates and ϵ is the error component. Countries are indexed $i = 1, ..., N$ and observed once per period $d = 1, ..., T$. To avoid the risk of endogeneity bias between food availability and trade policy, i.e. the possibility that trade policy may be influenced by the level of food availability, following Serrano-Domingo and Requena-Silvente (2013) we apply a 2SLS instrumental variable procedure. As a valid instrument we use the simple moving average of NRA in the previous decade which is supposed to be correlated with the current level of NRA but uncorrelated with any other determinants of food availability.[4]

Table 1: **Regression type estimates: dependent variable *food availability***

	OLS			**IV**		
	(1)	(2)	(3)	(4)	(5)	(6)
NAC	0.026***	0.142***	0.410***	0.044**	0.159	-2.240
	(0.008)	(0.032)	(0.134)	(0.021)	(0.114)	(2.59)
NAC^2		-0.041***	-0.234**		-0.038	1.645
		(0.011)	(0.094)		(0.039)	(1.843)
NAC^3			0.043**			-0.370
			(0.021)			(0.412)
lnreal pc GDP	0.419***	0.425***	0.428***	0.411***	0.392***	0.403***
	(0.059)	(0.059)	(0.059)	(0.067)	(0.067)	(0.079)
lnreal pc GDP^2	-0.023***	-0.023***	-0.024***	-0.023***	-0.022***	-0.021***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)
lnpc arable land	0.036***	0.036***	0.035***	0.037***	0.037***	0.042***
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.01)
food prod. index	0.002***	0.002***	0.002***	0.002***	0.002***	0.002***
	0.000	0.000	0.000	0.000	0.000	0.000
pop	0.504***	0.515***	0.519***	0.507***	0.523***	0.458***
	(0.095)	(0.095)	(0.094)	(0.097)	(0.097)	(0.132)
pop^2	-0.036***	-0.036***	-0.037***	-0.036***	-0.037***	-0.034***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.007)
No. of observations	1098	1098	1098	1091	1091	1091
R^2	0.579	0.586	0.588	0.578	0.581	0.423
Hausman test:				0.409	0.386	0.150
country FE	yes	yes	yes	yes	yes	yes
year FE	yes	yes	yes	yes	yes	yes

Note: $(NAC) = (1 + NRA)$
Standard errors in parenthesis. ***,**,* denote significance at the 1, 5 and 10 per cent level, respectively.

Table 1 reports both the OLS and the IV estimates of our panel analysis, with country and time fixed effects and robust standard errors. The coefficients of the food availability determinants[5] are highly significant and quite similar in both the OLS and IV estimates. NAC coefficients in the OLS and IV models are both significant as well, evidencing the consistency of both estimates. They loose significance in the IV model

[4] All the multivariate F-tests of excluded instruments reject the null hypothesis that the instruments are not correlated with the endogenous regressors. For column (4), the F-test is equal to 151.62 (p-value 0.000), for column (5) to 80.85 (p-value 0.000) and for column (6) to 54.67 (p-value 0.000).

[5] The covariates are selected according to the empirical literature on the macro drivers of food availability (Misselhorn, 2005; Feleke *et al.*, 2005; Garrett and Ruel, 1999; Iram and Butt, 2004; Rose, 1999; Pangaribowo *et al.*, 2013).

when the squared and cubic powers are introduced. The Hausman test does not reject the null hypothesis of the consistency of the parameters in the two models, confirming that the relationship between trade policy and food availability does not suffer from reverse causality. However, regression-type analyses do not rule out the risk of misspecification because of self-selection bias due to incomparable observations. For instance, the net food importer and exporter countries can be considered more likely to adopt agricultural trade distortions during the food price spikes and/or developing countries characterised by higher risks of food insecurity. Moreover, the most developed countries show on average relatively higher rates of protection. To deal with this issue, we apply the GPS approach.

5.2. GPS estimation and balancing property

As discussed in section 3, we first regress our measure of trade distortion on a set of pre-treatment observable characteristics and then estimate the GPS. Since the joint Jarque-Bera normality test strongly supports the null hypothesis of normal distribution of our treatment variable[6], we apply an OLS approach in the first stage estimation.

Table 2 presents the outcomes of the first stage equation for the aggregate case, as well as for wheat and rice. Notwithstanding the relevance of our set of covariates, it is worth recalling here that in impact evaluation exercises the functional form of the relationship as well as the interpretation and statistical significance of the individual effects of the covariates are of less importance than obtaining a powerful GPS (i.e. a GPS that works well in balancing the covariates by respecting the condition in eq. 3). In this regard, it is not irrelevant to add that the R-squared of our first stage regressions are high and consistent with similar GPS empirical exercises (Becker *et al.*, 2012; Serrano-Domingo and Requena-Silvente, 2013; Magrini *et al.*, 2014).

Inspection of the individual effects of the covariates for the aggregate exercise shows that NACs tend to be higher, the higher a country's per capita income (even if at a decreasing rate) and the lower the country's comparative advantage in agriculture (proxied by the percentage of arable land). A negative relationship between NAC and country dimension (proxied by the population size) is apparent as well (although not significant at the sectoral level).

The above empirical evidence is consistent with the well-known 'development pattern' whereby richer countries tend to maintain higher protection for domestic producers, while developing countries as well as bigger countries (proxied by population in thousands), tend to keep lower levels of NAC. Countries characterised by high dependence on food imports with respect to their total exports tend to maintain lower

[6] The p-value is 0.611, well above the standard 5% threshold of statistical significance.

Table 2: **Generalised Propensity Score Estimates**

	All		Wheat		Rice	
Covariates	Coef.	SE (robust)	Coef.	SE (robust)	Coef.	SE (robust)
lnreal pc gdp	0.988**	0.456	22.015***	5.675	-4.160***	1.043
lnreal pc gdp^2	-0.117**	0.055	-3.911***	1.030	0.518***	0.127
lnreal pc gdp^3	0.005**	0.002	0.305***	0.082	-0.021***	0.005
lnreal pc gdp^4			-0.009***	0.002		
ln pc arable land	-0.036***	0.006	-0.033***	0.006	-0.045***	0.012
pos dev food prices	-0.531***	0.142	0.071	0.128	-0.552***	0.193
neg dev food prices	-0.343***	0.107	-0.029	0.117	0.027	0.188
food price volatility	-1.345***	0.468	-1.278***	0.328	-0.492	0.376
food crisis	-0.048***	0.015	-0.051***	0.018	-0.049	0.034
food prod. index	0.000	0.000				
Asian DCs	-0.065***	0.017	-0.131***	0.039	0.019	0.033
Latin American DCs	-0.062***	0.018	-0.075**	0.032	0.082**	0.042
European Transition Economies	0.037**	0.019	-0.051	0.036	0.143**	0.066
High-income Countries	0.014	0.028	-0.049	0.044	0.272***	0.075
net food exporter	-0.057***	0.008	-0.154***	0.013	-0.203***	0.026
food import/total exports	-0.678*	0.397	-0.106	0.073	0.173	0.111
food import/total exports^2	2.816	1.760				
pop	-0.094***	0.025	-0.058	0.039	-0.064	0.086
pop^2	0.005***	0.001	0.003	0.002	0.002	0.004
cons	-2.379*	1.285	-45.576***	11.5611	11.347***	2.884
No. of observations	1072		901		630	
R^2	0.436		0.297		0.324	

$(NAC) = (1 + NRA)$.
All time variant variables with one lag.
Standard errors in parenthesis. ***,**,* denote significance at the 1, 5 and 10 per cent level, respectively.

levels of NAC as well since they tend to reduce the domestic prices of importables (Valdés and Foster, 2012). The 'anti-trade pattern' is also confirmed because countries with a comparative advantage in agriculture as well as net food exporters tend to protect less. The impacts of positive and negative deviations of international food prices from their trend are consistent with the goal of governments to use policies in order to stabilize the domestic markets. NACs are negatively correlated with positive international food price deviations from their trend, since food import restrictions tend to be eased during price spikes, and export tax tends to be raised. Consistently, NACs are negatively correlated with negative international food price deviations from their trend, since overall food import restrictions tend to be stressed during price drops while net exporter countries adopt a pro-trade behaviour (Anderson, 2013; Anderson and Nelgen, 2012c,a). However, on looking at the absolute value of the coefficient it appears that policy makers react more to price spikes than troughs. To be noted is that international food price volatility always impacts negatively on NACs, highlighting a strong correlation with trade distortions that imply lowering gross returns for domestic producers, probably because of the well-known depressive impact on consumption behaviour of price volatility. This impact is significantly influenced by the most recent observations in the database. Finally, as expected, net food exporting countries and developing countries in Asia and Latin America show, on average and *ceteris paribus*, lower NACs (i.e. higher export protection). Last but not least, lower NACs are recorded, on average and *ceteris paribus*, during the years of "food crisis".

The first stage estimates at the product level show consistent results. The main difference consists in the fact that the country dimension and the food import dependence variables are not significant in the product level exercises. In the case of wheat, both positive and negative deviations of international prices from trend are not significant either. In the case of rice, to be noted is the negative sign of the per capita GDP, coupled with the positive sign of the high income countries dummy. This means that while high income countries keep their markets protected, richer developing countries tend to show a lower level of NAC in the sector (i.e. higher export taxes). Furthermore, negative deviations of international prices from trend as well as price volatility appear to be not significant.

The second step of our impact evaluation exercise is to test the "balancing property". To this end, we compare the covariates across groups with and without the GPS correction. We first perform a series of two-sided t-tests across groups for each covariate (t-values reported in bold face indicate the presence of statistically significant differences at the 5% level). Four groups of approximately the same size are formed on the basis of the actual levels of NAC (three groups in the case of wheat and rice)[7]. As is apparent from Table A.4 in the Appendix, before controlling for the GPS, there are differences across the treatment groups with respect to the covariates for all the three cases. For the aggregate case, the average t-stat is 4.85 (well above the 1.96 threshold) and 52 out of 72 tests reject the balancing assumption (37 out of 51 in the case of wheat and 26 out of 48 in the case of rice). Once we condition on the value of the GPS score - building 8 strata for the aggregate case (10 for wheat and rice) - and impose the common support condition, the improvement in the balancing of the covariates is evident. The average t-stat reduces to 0.88 (0.98 for wheat and 0.46 for rice) and the balancing is still rejected in only 3 out of the 52 tests for the aggregate case (3 for wheat and 0 for rice). Table A.5 in the Appendix reports the final group-strata structure of the data. Figures B.2 to B.5 in the Appendix provide a succinct overview of the differences in the common support before and after GPS correction (for brevity only the aggregate case is reported). Figures B.6, B.7 and B.8 show the map of sample countries with the percentage of observations excluded by the common support in the various empirical exercises.

[7]We run t-tests for different numbers of groups before choosing the best combinations in terms of balancing properties

5.3. The Dose-Response Function

The last step is to estimate a dose-response function (DRF) illustrating, given the estimated GPS, if and how there is a causal link between NAC changes and the food security dimensions (eq.5). This requires testing a polynomial parametrization of the conditional expectation of the outcome as a function of observed treatment and estimated GPS as a flexible function of its two arguments (see section 3). It is useful to recall that, as Hirano and Imbens (2004) point out, also the estimated coefficients in this regression have no direct economic meaning except that of testing whether the covariates introduce any bias. While the GPS coefficients control for selection into treatment intensities, the interaction term shows the marginal impact of the treatment relative to the GPS. If selectivity matters, we expect both the GPS and the interaction coefficients to be statistically significant. This means that the GPS method highlights possible bias in outcomes that are actually controlled by looking over GPS strata as well as across them, by using the interaction term. If GPS is statistically significant, we denote the likely presence of self-selection bias (i.e. unobserved heterogeneity in treatment propensity that may be related to the variables of outcomes) for unmatched observations. As in Bia and Mattei (2008) we use bootstrap methods to obtain standard errors and confidence intervals of the DRF that take estimation of the GPS and the α parameters into account.

Once we had tested our DRF at different order of the polynomial terms, as in Egger *et al.* (2012) we chose to disregard those polynomial terms that proved to be insignificant in our OLS regression estimates. The corresponding results for the parsimonious, semi-parametric dose-response functions are summarised in Tables A.6; A.7; A.8; A.9 in the Appendix. To be noted is that also in this case R-squared is relatively high given the parsimonious specification and consistently with similar GPS empirical exercises (Becker *et al.*, 2012; Serrano-Domingo and Requena-Silvente, 2013; Magrini *et al.*, 2014) (lower in the wheat and rice cases).

The upper panels of Figs. 2 and 3 report the graphical representation of the point estimates of the DRF for the various dimensions of food security, i.e. the non-parametric functional form of the relationships between the food security dimensions and NCAs, while the bottom panels of the same figures depict the TEF, i.e. the first derivative of the respective DRF. The corresponding standard errors and 90% confidence intervals of both functions are also reported in the figures and were estimated via bootstrapping (see section 3). For brevity, all the Figures are here related to the aggregate case only (the wheat and rice cases are reported in the Appendix).

In the case of the food availability dimension of food security, we may presume that the aim of policy intervention is to increase food supply. As expected, the maximum increase is obtained for NAC values greater than 1. However, the positive (negative) impact of support (taxation) of the primary sector is

Figure 2: DRF and TEF: the aggregate case

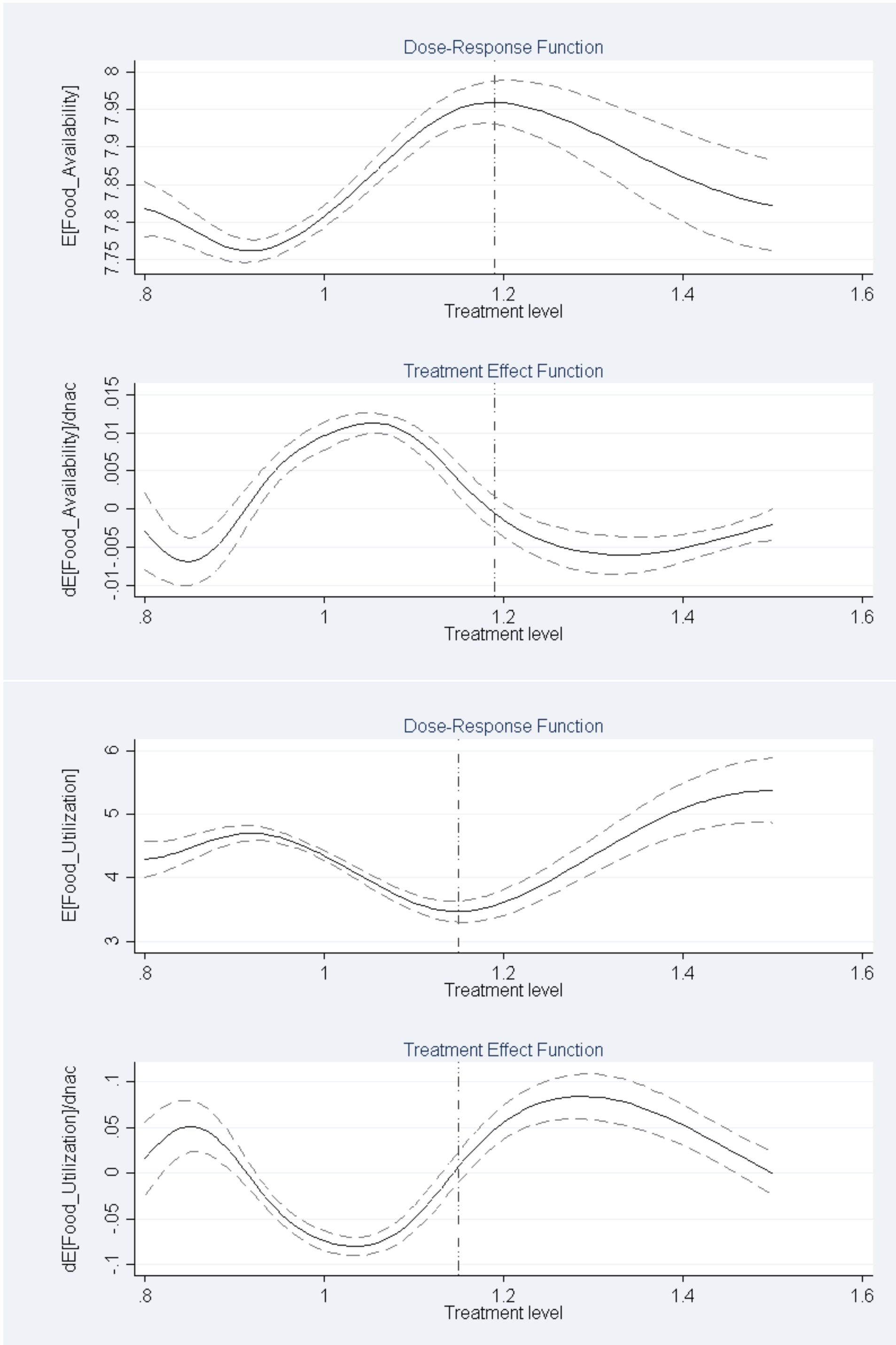
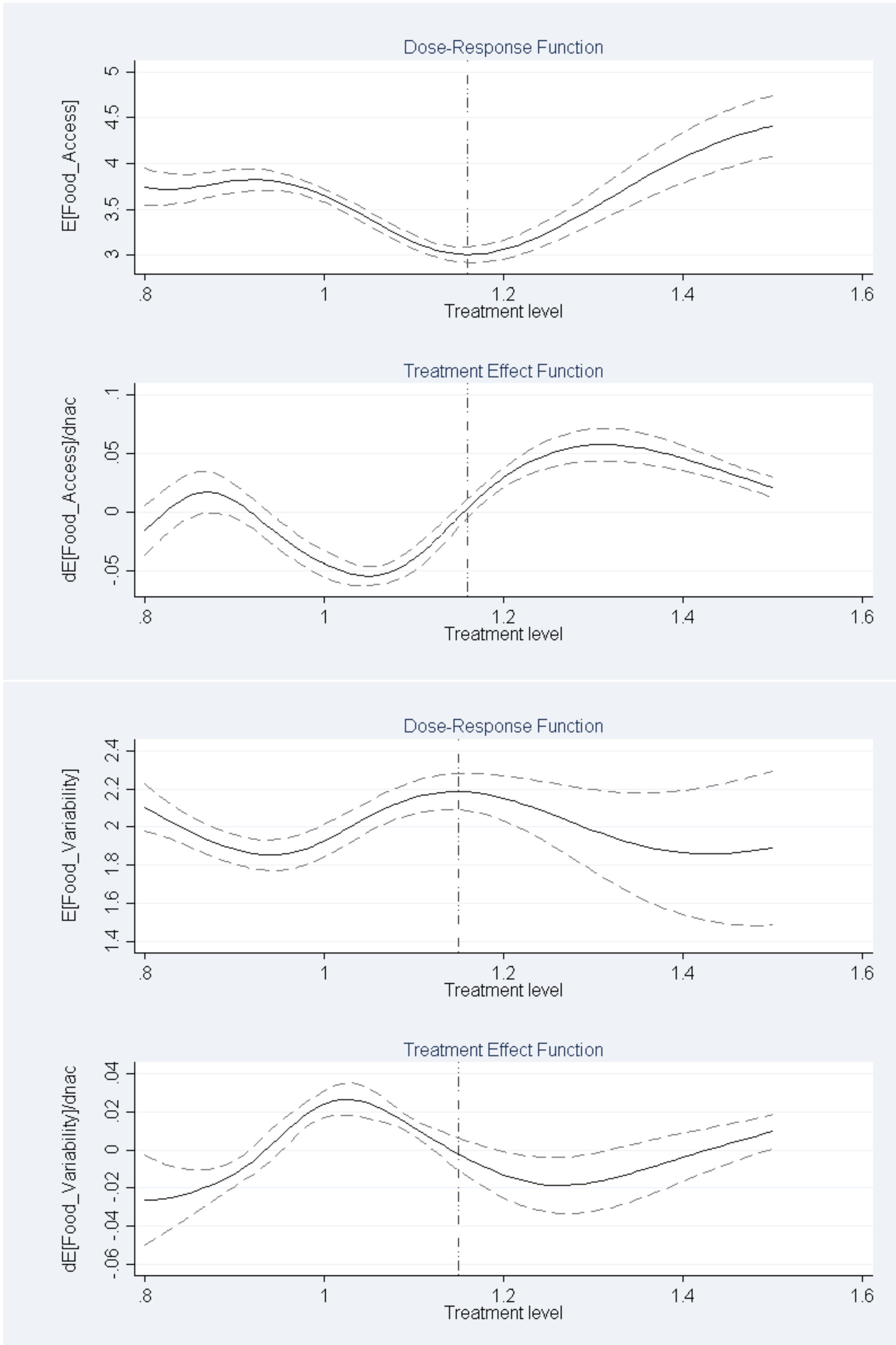


Figure 3: DRF and TEF: the aggregate case cont.d



confirmed only for a limited treatment range: NAC values greater than 1.2 have a negative impact on supply, while more severe taxation (i.e. NAC below 0.9) may actually increase it.

In the other food dimensions, the policy goals are associated with minimizing the response value. As far as food utilization is concerned, the depth of the food deficit is minimized for a NAC equal to 1.15. This implies that some support has a positive impact, while the opposite holds in the case of (even moderate) taxation, as well as in the case of larger support rates, although in the latter case the confidence intervals become quite large. A similar pattern is registered in the case of food access, since the lowest value for the infant mortality rate corresponds to a treatment of NAC equal to 1.18, while the worst performances are registered with NAC equal to 0.92 or NACs higher than 1.38.

Finally, also in the case of the food variability dimension, the treatment seems able to obtain a positive result, although the lowest per capita food supply variability is associated with a moderate taxation (NAC equal to 0.95) or very large support - though in the latter case the confidence intervals are huge. It is worth noting that treatment levels in the range associated with the best performances in the other dimensions would in this case lead to the worst result.

Table 3 provides a synthetic view of the average frequency of NAC by country and regional groups for the entire period under observation. As expected, African countries show the highest frequency of NAC below 1, while the developed ones show the highest frequency above 1.2. Note that 26 countries out of 75 show a NAC below 1 most of the time (Ivory Coast, Tanzania, Zimbabwe, Argentina, Nicaragua and Zambia virtually all the time), while 24 countries show a NAC higher than 1.2 most of the time (Iceland, Japan, South Korea, Morocco, Norway and Switzerland all of the time).

6. Conclusions

This paper has focused on the relationship between trade policy insulation and various dimensions of food security, on aggregate and by commodities. We have used a non-parametric method for causal inference in quasi-experimental settings with continuous treatment under the (weak) unconfoundedness assumption. We have shown the likely presence of a self-selection bias in the causal relationship between agricultural trade distortions and food security, cross-country and by product. Moreover, we have reported empirical evidence of a significant impact of agricultural trade policy distortions on the various dimensions of food security analysed.

The impact, however, is not consistent with the usual claims by free trade supporters that any policies would do more harm than good. Indeed, countries supporting the primary sector tend to be better off in

Table 3: **NAC frequencies by countries and regional groups, percentage (1990-2010)**

country	Below 1	Btw 1-1.2	Above 1.2	country	Below 1	Btw 1-1.2	Above 1.2
Australia	0	100	0	Denmark	0	29	71
Chile	0	100	0	France	0	29	71
New Zealand	0	100	0	Italy	0	29	71
USA	0	100	0	Portugal	0	29	71
Brazil	19	81	0	Spain	0	29	71
South Africa	19	76	5	Turkey	0	29	71
Malaysia	25	75	0	Ecuador	68	26	5
Mozambique	25	75	0	Egypt	75	25	0
China	24	71	5	Madagascar	75	25	0
Colombia	5	70	25	Finland	0	24	76
Sri Lanka	30	70	0	Germany	0	24	76
Poland	11	63	26	Slovenia	0	21	79
Uganda	38	63	0	Burkina Faso	80	20	0
Dominican Rep.	35	60	5	Mali	80	20	0
Kazakhstan	40	60	0	Austria	0	19	81
Kenya	40	60	0	Ireland	0	19	81
Mexico	14	57	29	Netherlands	0	19	81
Latvia	11	56	33	Sweden	0	19	81
Estonia	16	53	32	UK	0	19	81
Canada	0	52	48	Vietnam	56	19	25
Bulgaria	53	47	0	Togo	85	15	0
Czech Rep.	0	47	53	Zambia	94	6	0
Hungary	0	47	53	Nicaragua	95	5	0
Bangladesh	55	45	0	Argentina	95	5	0
India	40	45	15	Sudan	75	5	20
Nigeria	40	45	15	Ivory Coast	100	0	0
Philippines	5	45	50	Ethiopia	85	0	15
Romania	0	42	58	Iceland	0	0	100
Russia	11	42	47	Japan	0	0	100
Indonesia	60	40	0	South Korea	0	0	100
Thailand	60	40	0	Morocco	0	0	100
Chad	63	38	0	Norway	0	0	100
Slovakia	0	38	63	Switzerland	0	0	100
Lithuania	16	37	47	Tanzania	100	0	0
Ukraine	63	37	0	Zimbabwe	100	0	0
Cameroon	65	35	0	Africa	65	28	7
Benin	69	31	0	Asia	38	44	18
Senegal	63	31	6	South America	40	52	8
Ghana	55	30	15	Transition Ctrs	14	43	42
Pakistan	70	30	0	Developed Ctrs	0	32	68
				Total	31	37	32

most dimensions of food security (food availability, access, and utilisation) while taxation of the primary sector tends to reduce variability. The policy implications, therefore, are not consistent in terms of sign; and even in the case of support, the "'optimal"' intensity varies across dimensions and there is ample evidence that governments may be tempted to provide "too much of a good thing", since the highest levels of support are associated with negative performances in terms of food security. More generally, our analysis does not allow normative implications to be drawn, since we have not considered the costs of the treatment. However, the evidence of a positive impact in terms of food security is certainly important, and it justifies further analysis of the actual policy mixes adopted in correspondence to different treatment levels.

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Appendix A. Tables & Figures

Table A.1: **List of sampled countries (general case) and summary statistics for the aggregate NRA**

Country	mean	sd	min	max	Country	mean	sd	min	max
Argentina	-0.116	0.099	-0.236	0.004	Malaysia	-0.008	0.047	-0.134	0.037
Australia	0.024	0.016	0.005	0.064	Mali	-0.020	0.028	-0.099	0.016
Austria	0.420	0.228	0.066	0.821	Mexico	0.140	0.130	-0.151	0.413
Bangladesh	-0.020	0.070	-0.154	0.138	Morocco	0.516	0.087	0.328	0.667
Benin	-0.013	0.019	-0.069	0.005	Mozambique	0.027	0.037	-0.050	0.090
Bulgaria	-0.016	0.103	-0.232	0.183	Newzealand	0.023	0.014	0.004	0.064
Burkinafaso	-0.026	0.054	-0.199	0.021	Nicaragua	-0.089	0.079	-0.229	0.052
Cameroon	-0.004	0.016	-0.030	0.049	Nigeria	0.065	0.180	-0.087	0.722
Chad	-0.006	0.012	-0.038	0.012	Norway	0.977	0.243	0.613	1.240
Chile	0.059	0.035	0.004	0.102	Pakistan	-0.027	0.076	-0.216	0.123
Colombia	0.162	0.090	-0.036	0.341	Philippines	0.202	0.129	-0.059	0.411
Coted'ivoire	-0.197	0.019	-0.233	-0.169	Poland	0.175	0.139	-0.017	0.596
Czechrep	0.212	0.118	0.066	0.484	Portugal	0.264	0.110	0.082	0.438
Denmark	0.340	0.181	0.063	0.697	Romania	0.331	0.249	0.036	0.798
Dominicanrepubli	0.036	0.132	-0.203	0.281	South Africa	0.051	0.070	-0.067	0.213
Ecuador	-0.043	0.125	-0.212	0.219	Russia	0.176	0.134	-0.197	0.419
Egypt	-0.036	0.082	-0.202	0.104	Senegal	-0.015	0.115	-0.172	0.226
Estonia	0.151	0.154	-0.196	0.488	Slovakia	0.246	0.123	0.066	0.426
Ethiopia	-0.081	0.275	-0.226	0.892	Slovenia	0.564	0.286	0.092	1.056
Finland	0.479	0.377	0.068	1.260	Srilanka	0.041	0.114	-0.221	0.192
Ghana	0.045	0.136	-0.064	0.468	Sudan	0.107	0.316	-0.209	0.826
Hungary	0.205	0.121	0.065	0.446	Sweden	0.460	0.298	0.066	1.128
Iceland	0.992	0.287	0.597	1.228	Switzerland	0.676	0.196	0.469	0.976
India	0.055	0.124	-0.128	0.260	Tanzania	-0.112	0.058	-0.174	0.000
Indonesia	-0.014	0.106	-0.218	0.138	Thailand	-0.004	0.061	-0.093	0.149
Ireland	0.572	0.263	0.078	1.051	Togo	-0.015	0.019	-0.072	0.003
Kazakhstan	0.009	0.097	-0.146	0.100	Turkey	0.247	0.113	0.013	0.432
Kenya	0.029	0.063	-0.078	0.158	Uganda	0.001	0.007	-0.022	0.009
Korea	0.924	0.285	0.483	1.244	Ukraine	-0.027	0.093	-0.192	0.135
Latvia	0.217	0.168	0.032	0.541	Vietnam	0.045	0.177	-0.231	0.322
Lithuania	0.199	0.216	-0.198	0.653	Zambia	-0.079	0.128	-0.224	0.134
Madagascar	-0.043	0.047	-0.127	0.063	Zimbabwe	-0.191	0.042	-0.227	-0.142
					Total	0.126	0.258	-0.236	1.260

Table A.2: **Variables and Data**

Type	**Variable**	**Source**
Trade distortions (treatment)	Nominal Rates of Assistance (NRAs) by product:	
	sum of NRA to output conferred by border market price support,	
	NRA to output conferred by domestic price support and NRA to inputs.	World Bank dataset (Anderson and Nelgen, 2012),
		"Updated National and Global Estimates of Distortions to Agricultural Incentives, 1955 to 2010")
	Aggregate Nominal Rates of Assistance (NRAag):	
	Value of production-weighted average NRA all (primary) Agriculture,	
	total for covered and non-covered and non-product-specific assistance.	
Observable characteristics (covariates)	Per capita GDP (2005 International USD).	Penn World Table (Heston, Summers and Aten, 2012, "Penn World Table Version 7.1",
		Center for International Comparisons of Production,
		Income and Prices at the University of Pennsylvania, November)
	Population (in thousands).	
	Arable land (hectares per person).	World Bank - World Development Indicators
	Food production index (only food crops that are considered edible and that contain nutrients)	
	Food imports over total exports	FAOSTAT; IMF DOTS
	Deviation of international food prices from trend (positive and negative, %)	World Bank - GEM Commodity Price Data
	International food price volatility	
	Dummy for net exporter (=1 if yes)	FAOSTAT
	Dummies for Regional groups: African Developing Countries (Group 1);	
	Asian Developing Countries (Group 2);	
	Latin American Developing Countries (Group 3);	
	European Transition Economies (Group4);	
	High-income Countries (Group 5).	World Bank dataset (Anderson and Nelgen, 2012
	Dummy for food crisis (=1 if year= 2007 and 2008)	Authors calculation.
Food Security dimensions (outcome):		
Availability	Food supply (in kcal/capita/day).	FAO - Food Balance Sheets
Access	Depth of food deficit (kilocalories per person per day).	World Bank - World Development Indicators
Utilization	Mortality rate, infant (per 1,000 live births).	World Bank - World Development Indicators
Stability	Per capita food supply variability (standard deviation over 5 years of the deviation from the trend of per capita food supply).	FAO

Table A.3: **Summary statistics of covariates**

Variable	**Mean**	**Std. dev.**	**Min**	**Max**	**Observations**
Real per-capita GDP	9714.136	11148.370	323.260	51791.630	1072
Population	52636.59	138142.9	269	1156898	1072
Per-capita arable land	0.328	0.348	0.030	2.807	1072
Food production index	89.646	15.895	35.020	148.220	1072
Food import/total exports	0.016	0.024	0.001	0.260	1070
Pos. deviation of int.l food prices	0.010	0.030	0.000	0.142	1072
Neg. deviation of int.l food prices	0.050	0.041	0.000	0.138	1072
Food price volatility	0.021	0.009	0.006	0.050	1072
Net food exporter	0.484	0.500	0.000	1.000	1072
Group 1 - African DCs	0.332	0.471	0.000	1.000	1072
Group 2 -Asian DCs	0.170	0.376	0.000	1.000	1072
Group 3 - Latin American DCs	0.119	0.324	0.000	1.000	1072
Group 4 - European Transition Economies	0.205	0.404	0.000	1.000	1072
Group 5 - High-income Countries	0.174	0.379	0.000	1.000	1072
Food crisis	0.090	0.287	0.000	1.000	1072
Food supply	2725.312	524.468	1557.000	3826.000	1044
Infant mortality	40.190	36.564	1.900	155.100	1072
Depth of food deficit	97.958	110.173	1.000	615.000	985
Food variability	12.671	13.378	0.509	81.396	1045

Table A.4:

Differences in the treatment levels before and after balancing on the GPS: t-stats for equality of means.

	Aggregate							
	Prior to balancing on the GPS				After balancing on the GPS			
Covariates	**Group 1**	**Group 2**	**Group 3**	**Group 4**	**Group 1**	**Group 2**	**Group 3**	**Group 4**
lnreal pc gdp	**13.921**	**8.091**	**5.536**	**17.173**	1.957	1.120	1.373	0.506
lnreal pc gdp^2	**13.993**	**7.770**	**5.064**	**17.485**	1.906	0.999	1.338	0.385
lnreal pc gdp^3	**13.984**	**7.405**	**4.570**	**17.681**	1.852	0.867	1.293	0.265
lnreal pc gdp^4								
ln pc arable land	**2.357**	**3.953**	**2.347**	0.768	1.226	1.532	1.873	0.872
pos dev food prices	0.879	1.184	**3.357**	1.279	0.463	0.313	0.996	0.095
neg dev food prices	0.743	0.370	**1.979**	0.863	0.434	0.143	0.300	0.515
food price volatility	1.082	0.483	**2.295**	0.725	0.385	0.166	0.621	0.928
food crisis	0.307	1.045	**3.146**	1.784	0.130	0.405	0.613	1.542
food prod. index	**6.334**	**6.356**	**4.523**	**8.227**	0.150	1.115	1.371	1.008
Asian DCs	**3.301**	0.094	0.657	**4.067**	0.555	0.154	0.631	0.019
Latin American DCs	**2.397**	**2.836**	**5.058**	**4.609**	0.007	1.361	1.693	0.084
European Transition Economies	**6.033**	**7.520**	**6.401**	**7.144**	0.246	**2.382**	0.400	0.379
High-income Countries	**8.973**	1.210	**2.708**	**13.604**	0.988	**2.010**	0.530	0.479
net food exporter	**3.905**	**2.048**	0.352	**6.393**	0.673	0.405	0.958	0.159
food import/total exports	**5.381**	**6.281**	**4.645**	**7.036**	1.257	1.253	1.001	0.768
food import/total exports^2	**2.194**	**4.570**	**2.870**	**3.883**	1.075	0.969	0.724	0.684
pop	**6.572**	1.203	1.924	**7.340**	1.406	**1.972**	0.696	1.088
pop^2	**6.333**	1.587	**2.046**	**6.819**	1.395	1.957	0.696	0.984
No. of observations	268	268	268	268	243	246	217	114
Mean t-value	4.848				0.876			

	Wheat					
	Prior to balancing on the GPS			After balancing on the GPS		
Covariates	**Group 1**	**Group 2**	**Group 3**	**Group 1**	**Group 2**	**Group 3**
lnreal pc gdp	**2.572**	**4.708**	**2.102**	0.760	1.459	1.810
lnreal pc gdp^2	**2.534**	**4.717**	**2.149**	0.808	1.477	1.863
lnreal pc gdp^3	**2.511**	**4.708**	**2.163**	0.853	1.487	1.904
lnreal pc gdp^4	**2.499**	**4.683**	**2.151**	0.893	1.490	1.932
ln pc arable land	**2.433**	**4.771**	**7.380**	0.784	1.035	0.538
pos dev food prices	1.490	**3.300**	1.803	0.560	0.979	0.074
neg dev food prices	**4.820**	**3.192**	1.594	1.206	0.887	0.324
food price volatility	**7.988**	**2.437**	**5.397**	1.022	0.974	0.359
food crisis	**8.915**	**4.255**	**4.397**	**2.136**	1.556	0.714
food prod. index						
Asian DCs	1.508	**2.648**	1.137	0.190	1.112	1.078
Latin American DCs	0.809	0.114	0.698	0.393	0.066	0.112
European Transition Economies	**7.128**	**2.759**	**4.247**	**2.059**	1.035	0.116
High-income Countries	**5.716**	**5.304**	0.394	1.896	**2.058**	1.223
net food exporter	**7.379**	**4.378**	**12.510**	0.438	0.537	0.715
food import/total exports	0.334	**4.575**	**4.248**	0.086	1.446	1.483
food import/total exports^2						
pop	1.656	0.661	**2.330**	0.549	0.207	1.333
pop^2	1.347	0.882	**2.243**	0.376	0.258	1.332
No. of observations	302	302	297	283	293	271
Mean t-value	3.464			0.980		

	Rice					
	Prior to balancing on the GPS			After balancing on the GPS		
Covariates	**Group 1**	**Group 2**	**Group 3**	**Group 1**	**Group 2**	**Group 3**
lnreal pc gdp	**5.007**	0.552	**4.450**	0.284	0.580	0.567
lnreal pc gdp^2	**5.011**	0.826	**4.162**	0.291	0.610	0.592
lnreal pc gdp^3	**4.972**	1.085	**3.848**	0.299	0.634	0.613
lnreal pc gdp^4						
ln pc arable land	**3.020**	**5.048**	**2.057**	0.334	0.803	0.117
pos dev food prices	**2.380**	**2.437**	0.098	0.574	0.854	0.517
neg dev food prices	0.805	1.603	0.830	0.423	0.652	0.271
food price volatility	1.207	0.824	0.372	0.065	0.690	0.206
food crisis	0.225	0.289	0.070	0.060	0.111	0.265
food prod. index						
Asian DCs	**7.087**	**3.038**	**3.824**	0.127	0.722	0.325
Latin American DCs	**5.917**	0.379	**5.545**	0.708	0.801	0.901
European Transition Economies	1.610	0.491	**2.129**	0.307	0.160	0.228
High-income Countries	**3.266**	**1.989**	1.232	0.325	0.583	0.570
net food exporter	**5.896**	**2.184**	**3.590**	0.369	0.152	0.803
food import/total exports	0.474	1.653	1.214	0.541	0.592	0.871
food import/total exports^2						
pop	**7.186**	1.775	**5.258**	0.109	0.250	0.911
pop^2	**7.371**	1.899	**5.300**	0.121	0.287	0.875
No. of observations	207	222	201	178	209	182
Mean t-value	2.740			0.457		

Note: t-values reported in bold face indicate null rejections at the 5% level significance.

Table A.5: **The final group-strata structure**

Aggregate

Strata	Control1	Group1	Control2	Group2	Control3	Group3	Control4	Group4
1	200	31	88	31	218	28	410	15
2	134	30	75	31	96	27	77	14
3	52	31	71	31	42	27	28	14
4	35	30	70	30	44	27	72	14
5	41	30	60	31	54	27	28	15
6	43	31	63	31	67	27	38	14
7	46	30	84	31	31	27	18	14
8	26	30	63	30	51	27	34	14

Wheat

Strata	Control1	Group1	Control2	Group2	Control3	Group3
1	199	29	102	30	249	28
2	85	28	47	29	89	27
3	74	28	64	29	46	27
4	70	29	84	30	39	27
5	36	28	52	29	47	27
6	18	28	61	29	28	27
7	31	29	36	30	52	27
8	16	28	31	29	15	27
9	16	28	52	29	6	27
10	19	28	25	29	4	27

Rice

Strata	Control1	Group1	Control2	Group2	Control3	Group3
1	128	18	104	21	100	19
2	70	18	46	21	47	18
3	40	18	31	21	80	18
4	39	18	38	21	58	18
5	39	18	23	21	30	18
6	49	18	26	21	27	19
7	14	18	19	21	25	18
8	5	18	28	21	12	18
9	5	18	23	21	3	18
10	2	17	23	20	5	18

Figure A.1: **Common support before and after GPS (aggregate case): group 1**

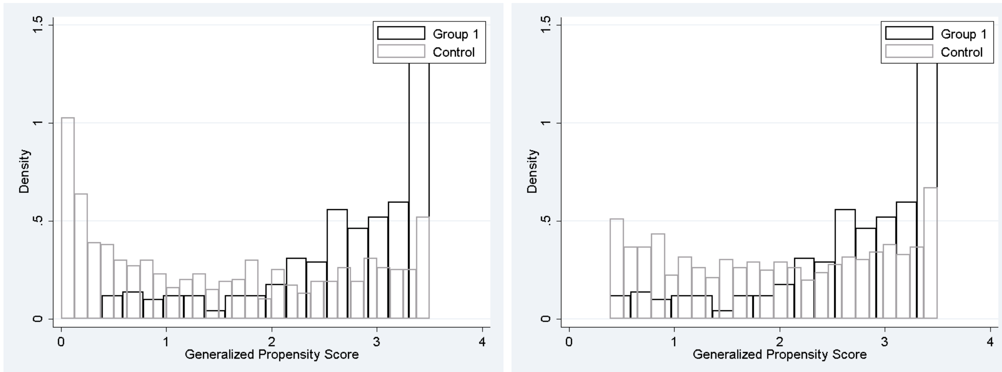


Figure A.2: **Common support before and after GPS (aggregate case): group 2**

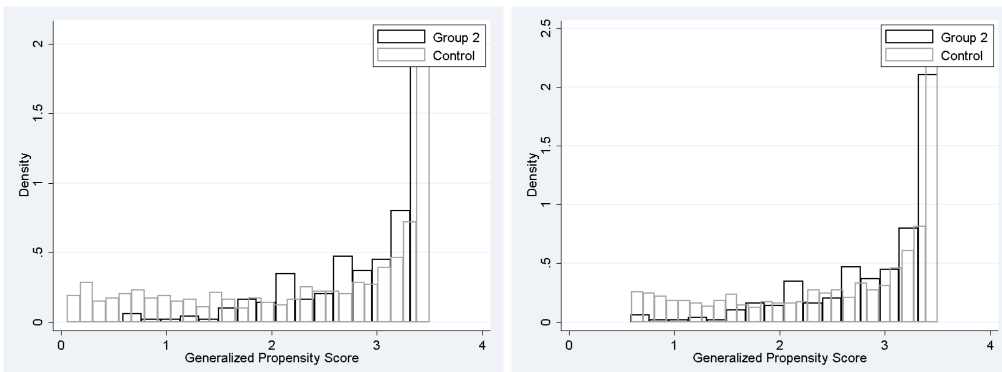


Figure A.3: **Common support before and after GPS (aggregate case): group 3**

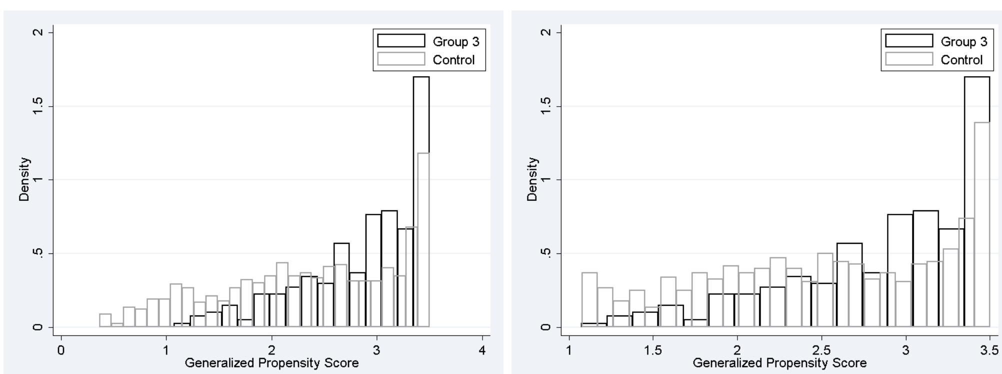
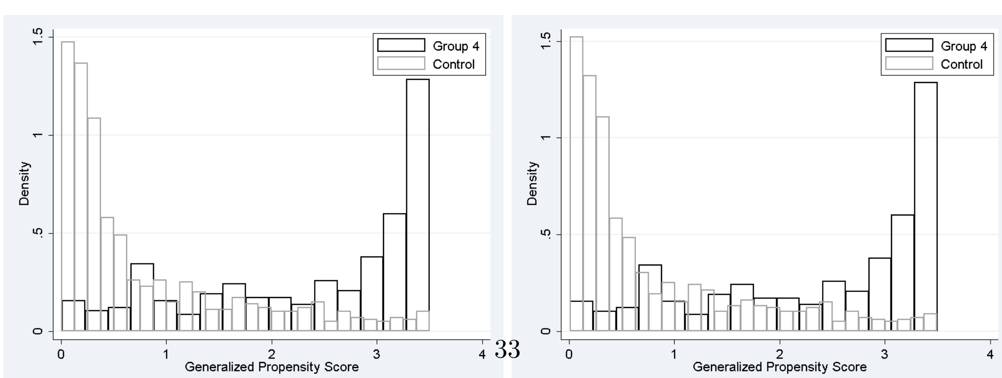
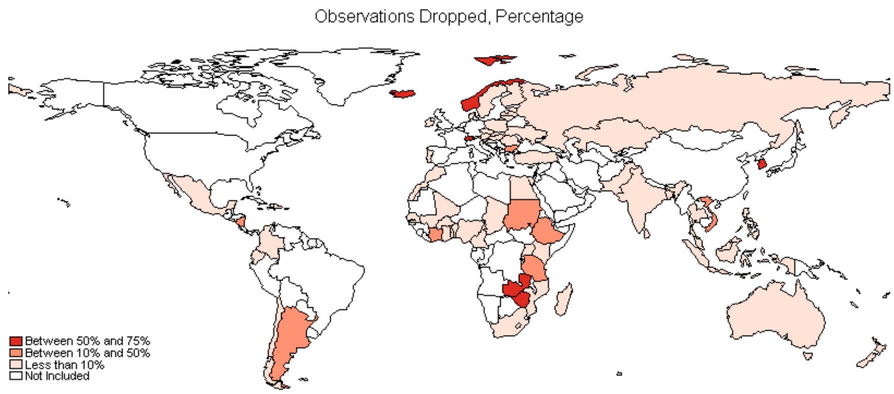


Figure A.4: **Common support before and after GPS (aggregate case): group 4**



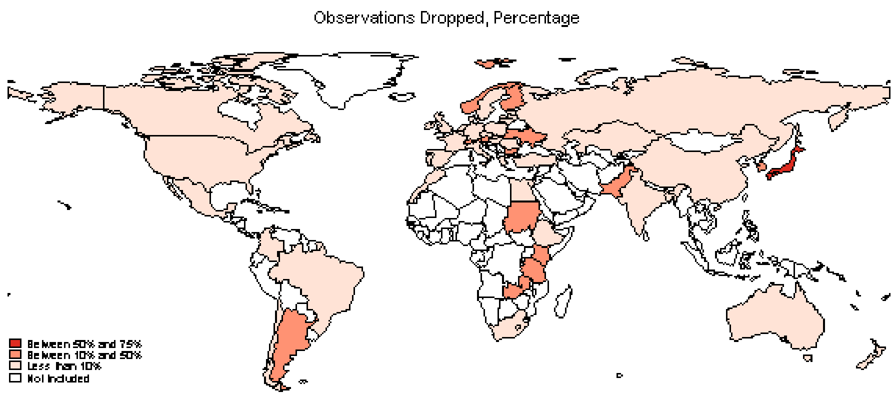
Source: Authors' calculations

Figure A.5: **Map of countries (% of observations excluded by the common support: the general case)**



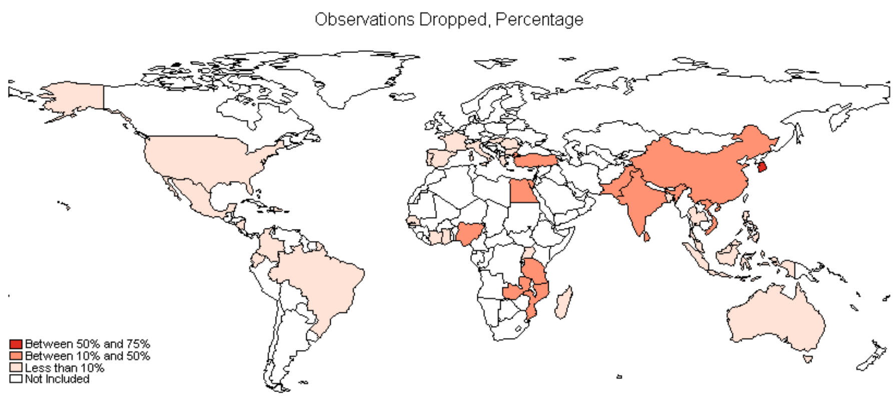
Source: Authors' calculations

Figure A.6: **Map of countries (% of observations excluded by the common support: the wheat case)**



Source: Authors' calculations

Figure A.7: **Map of countries (% of observations excluded by the common support: the rice case)**



Source: Authors' calculations

Table A.6: **DRF estimation for food availability**

Food Availabity	Aggregate		Wheat		Rice	
	Coef.	SE (robust)	Coef.	SE (robust)	Coef.	SE (robust)
NAC	5.620***	1.889	-0.237	0.158	-0.938***	0.347
NAC^2	-4.640***	1.499	0.093**	0.046	0.561***	0.198
NAC^3	1.220***	0.384			-0.091***	0.035
GPS	-0.354***	0.070	0.092**	0.048	0.757***	0.157
GPS^2	-0.071**	0.040	-0.012	0.011	-0.597***	0.159
GPS^3	0.014**	0.007			0.146***	0.045
NAC*GPS	0.404***	0.034	0.000	0.029		
cons	5.704***	0.755	8.034***	0.110	8.062***	0.178
No. of observations	806		814		561	
R^2	0.3062		0.044		0.087	

Note: $(NAC) = (1 + NRA)$
***,**,* denote significance at the 1, 5 and 10 per cent level, respectively.

Table A.7: **DRF estimation for food access**

Food Access	Aggregate		Wheat		Rice	
	Coef.	SE (robust)	Coef.	SE (robust)	Coef.	SE (robust)
NAC	-42.914***	10.376	2.957***	0.720	1.521	1.543
NAC^2	35.971***	8.395	-1.159***	0.215	-1.211	0.858
NAC^3	-9.460***	2.191			0.224	0.145
GPS	1.468***	0.347	-0.856***	0.265	-2.782***	0.799
GPS^2	0.421**	0.195	0.067	0.059	2.335***	0.809
GPS^3	-0.061**	0.034			-0.607***	0.232
NAC*GPS	-2.104***	0.161	0.156	0.144		
cons	19.858***	4.085	1.907***	0.523	3.759***	0.780
No. of observations	820		847		570	
R^2	0.2156		0.123		0.052	

Note: $(NAC) = (1 + NRA)$
***,**,* denote significance at the 1, 5 and 10 per cent level, respectively.

Table A.8: **DRF estimation for food utilization**

Food Utilization	Aggregate		Wheat		Rice	
	Coef.	SE (robust)	Coef.	SE (robust)	Coef.	SE (robust)
NAC	-78.439***	23.487	2.854**	1.469	6.814**	3.161
NAC^2	70.240***	19.509	-1.076***	0.442	-4.160**	1.789
NAC^3	-19.813***	5.251			0.676**	0.307
GPS	3.236***	0.626	-0.681	0.471	-5.866***	1.528
GPS^2	0.583*	0.341	0.051	0.106	4.330***	1.559
GPS^3	-0.104*	0.058			-0.976**	0.448
NAC*GPS	-3.893***	0.278	-0.044	0.270		
cons	31.989***	9.000	2.199**	1.024	2.649	1.608
No. of observations	749		785		519	
R^2	0.2659		0.063		0.059	

Note: $(NAC) = (1 + NRA)$
***,**,* denote significance at the 1, 5 and 10 per cent level, respectively.

Table A.9: **DRF estimation for food variability**

Food Variability	Aggregate		Wheat		Rice	
	Coef.	SE (robust)	Coef.	SE (robust)	Coef.	SE (robust)
NAC	-6.118***	1.843	0.009	0.850	-0.520	1.544
NAC^2	2.484***	0.706	0.063	0.265	0.351	0.872
NAC^3					-0.052	0.143
GPS	-1.127***	0.187	0.371	0.240	1.462**	0.748
GPS^2		0.196	0.058	0.053	-0.958	0.737
GPS^3				0.144	0.209	0.209
NAC*GPS	1.115***	1.078	-0.348***	0.577		
cons	5.582***		2.069***		1.551**	0.728
No. of observations	808		818		570	
R^2	0.0847		0.052		0.019	

Note: $(NAC) = (1 + NRA)$
***,**,* denote significance at the 1, 5 and 10 per cent level, respectively.

Figure A.8: DRF and TEF: the wheat case

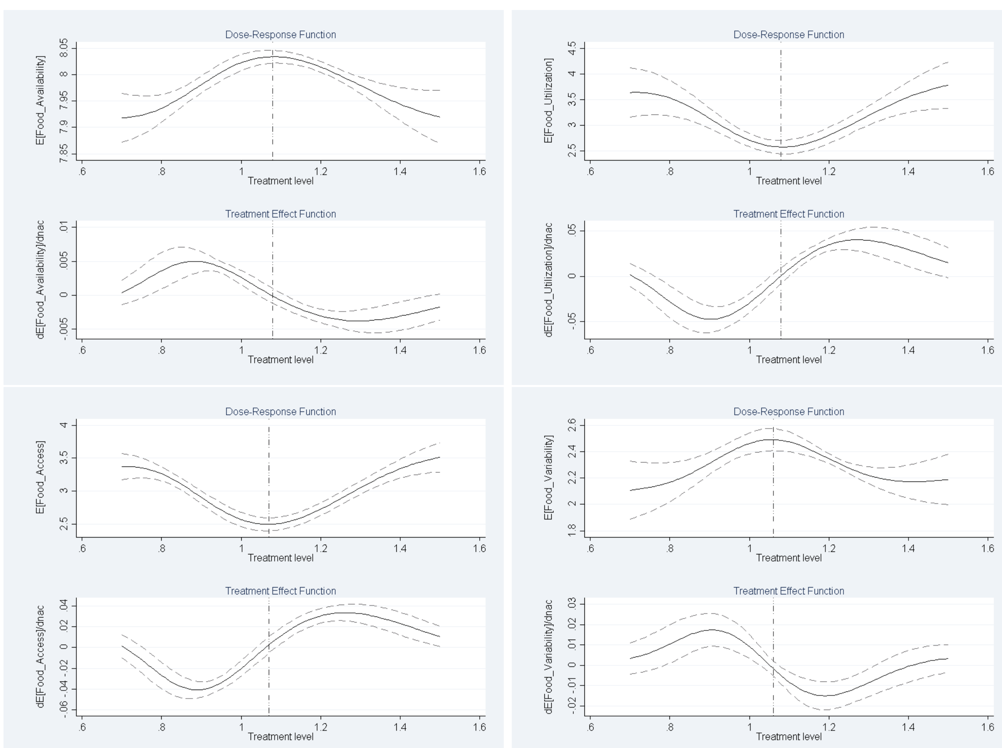
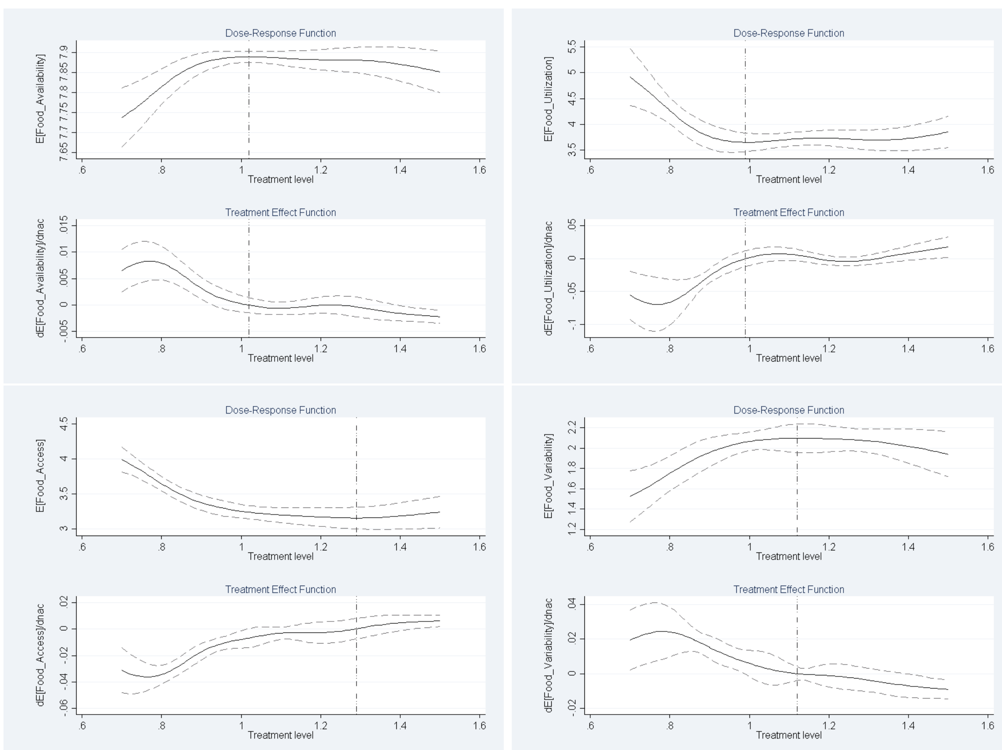


Figure A.9: DRF and TEF: the rice case



FOODSECURE
FOR POLICIES THAT MATTER

The FOODSECURE project in a nutshell

Title	FOODSECURE – Exploring the future of global food and nutrition security
Funding scheme	7th framework program, theme Socioeconomic sciences and the humanities
Type of project	Large-scale collaborative research project
Project Coordinator	Hans van Meijl (LEI Wageningen UR)
Scientific Coordinator	Joachim von Braun (ZEF, Center for Development Research, University of Bonn)
Duration	2012 - 2017 (60 months)

Short description

In the future, excessively high food prices may frequently reoccur, with severe impact on the poor and vulnerable. Given the long lead time of the social and technological solutions for a more stable food system, a long-term policy framework on global food and nutrition security is urgently needed.

The general objective of the FOODSECURE project is to design effective and sustainable strategies for assessing and addressing the challenges of food and nutrition security.

FOODSECURE provides a set of analytical instruments to experiment, analyse, and coordinate the effects of short and long term policies related to achieving food security.

FOODSECURE impact lies in the knowledge base to support EU policy makers and other stakeholders in the design of consistent, coherent, long-term policy strategies for improving food and nutrition security.

EU Contribution	€ 8 million
Research team	19 partners from 13 countries

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SEVENTH FRAMEWORK PROGRAMME