Agricultural Trade Policy Distortions and Food Security: Is there a Causal Relationship?

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Abstract

The aim of this paper is to assess the causal impact of trade policy distortions on food security. This is an hot issue since restrictions to agricultural trade have been generally applied by national governments, especially in developing countries, as a tool to insulate domestic markets from international prices turmoil. The added value of this work is twofold: i) the use of a non parametric matching technique with continuous treatment, namely the Generalised Propensity Score (GPS) to address the self selection bias; ii) the analysis of treatment (by commodities) as well as outcome heterogeneity (i.e., different dimensions of food security). The outcomes of our estimates show clearly that trade policy distortions are, overall, significantly correlated with the various dimensions of food security under analysis but on the opposite direction than hoped for by policy-makers: countries less prone to adopt trade distortion policies tend to be better off in all the dimensions of food security (food availability, access, utilisation) with the relevant exception of food stability.

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

JEL classification: C21, F14, Q17, Q18

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1. Introduction

Countries usually adopt restrictions in agricultural trade in the attempt to insulate domestic markets from food price turmoil (Anderson *et al.*, 2013). The debate about the effectiveness of these measures is hot and timely. While most part of the literature is currently focusing on the impact on price level and volatility (Anderson and Nelgen, 2012a,b), less attention has been devoted to the impact of these trade restrictions on food security.

The current paper contributes to the literature on the relationship between trade policy and food security in two ways. First, we apply 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, we control for treatment heterogeneity as well as for outcome heterogeneity in order to investigate the presence of different causal relationships by policy and product coverage and various dimensions of food security.

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), and also the relationship between migration and trade (Egger *et al.*, 2012). To the best of our knowledge this is the first GPS application to the 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 the empirical evidence of a significant impact of agricultural trade distortions on the various dimensions of food security under analysis. However, it holds on the opposite direction than hoped for by policy-makers: countries less prone to adopt trade distortion policies tend to be better off in all the dimensions of food security (food availability, access, utilisation) with the relevant exception of food stability. .

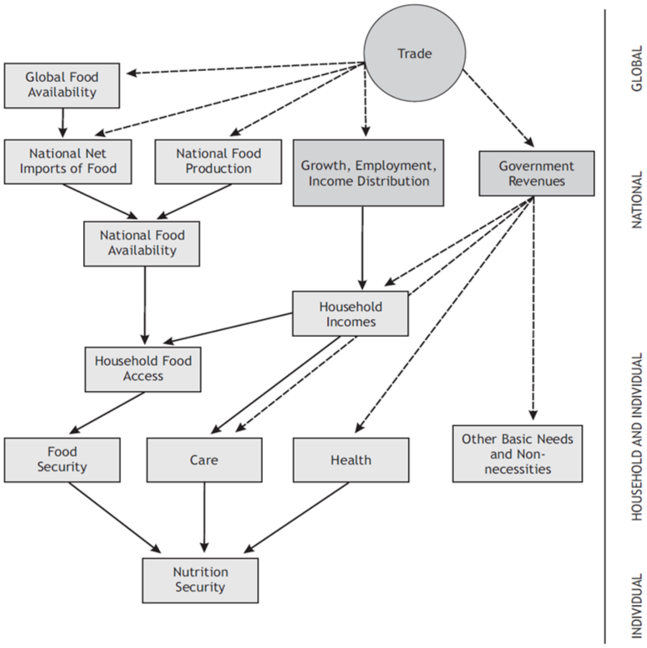
The work is organised as follows: Section 2 briefly summarises, theoretically and empirically, the links between trade and food security; Section 3 presents the GPS estimator; Section 4 describes variables and data; Section 5 shows the empirical results; Section 6 concludes.

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

2.1. The conceptual framework

Trade and food security are closely interconnected. Both trade and trade policy affect food security, directly through the impact on food availability, and indirectly through the effects on food accessibility and stability. Diaz-Bonilla *et al.* (2002) were among the first to analyse the interactions among these issues and to emphasise the variety of impacts that trade and trade policies can have on the determinants of food security. Fig. 1 proposes a conceptual framework for food security, which 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 by which trade and trade policies influence food security is both via their impact on 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 both on the level and the stability of the rate of growth, as well as on the employment, income distribution, and poverty. A third channel is through government revenues, directly (as collection of trade taxes) and indirectly (through their impact on the rate and variability of growth)(Diaz-Bonilla and Ron, 2010). 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 profits of food producers and food costs to consumers, mainly because of their effect (both on levels and volatility) on world and domestic food prices. Concerning price level, high food prices can impact positively on food availability, improving food production and its access by increasing producers' incomes. At the same time, it 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 both on the production and consumer side. Producers react to extreme/unpredictable price volatility, under-investing or investing in "wrong projects" (Caballero, 1991; Bertola and Caballero, 1994; Aizenman and Marion, 1994); consumers 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 true for producers (HLPE, 2011).

2.2. A naive theoretical framework

Because of the pervasive role of prices to food security, pro-cyclical trade policies are often applied as an efficient measure to insulate domestic markets from international price turmoil. Although justifications for such trade measures can be multiple, food security has been claimed as the dominant reason for resorting to trade measures in the recent food price crises (Rutten *et al.*, 2013). Any country with a significant share of its population being food insecure, or bearing a high risk of becoming so, faces a strong pressure to adopt policy measures to avoid the problems due to the rise in domestic food prices (Anania, 2013). The set of trade policy measures adopted to insulate price rising varies in many respects. They include both export restrictions adoption as well as import restrictions relaxation[1]. These measures are different in their transparency and in the administrative burden involved in their implementation and have different distributional effects. The extent of the impact of these kind of policies for the world market depends on a number of factors, including the size of the country adopting them; the characteristics of world demand and supply of the specific product; whether the increase in the international price is product specific or not; the volume of the product traded internationally relative to world production (Anania, 2013).

To facilitate the understanding of the impacts of trade restrictions on prices, exports, and welfare as well as the interpretation of our empirical outcomes, we propose a simple theoretical framework, reported in Fig. 2. For brevity, we analyse only the economic effects of the adoption of export taxes - since this is the typical emergency measure adopted in reaction to soaring international prices and aiming at safeguarding food security - both in a small and in a large exporting country trading one (agricultural) good with the rest of the world.

Assuming that P_1 is the "undistorted" domestic price level - it equals international price P_w - at this price

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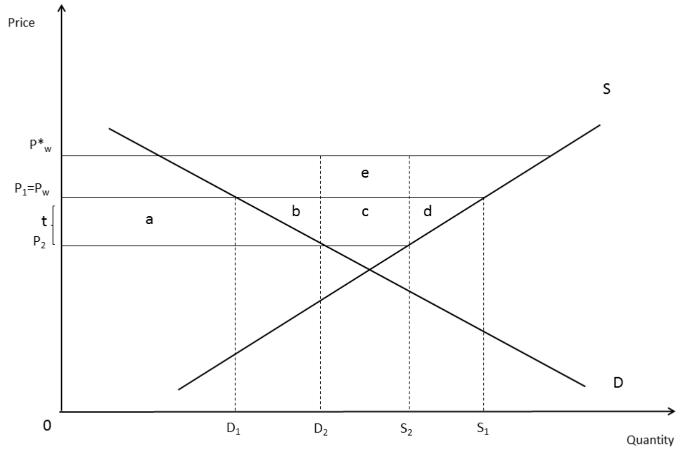
[1] It is worth noting that an export tax (or import subsidy) is the equivalent of a consumer subsidy and a producer tax, while an import tax (or export subsidy) is the equivalent of a consumer tax and a producer subsidy.

Figure 2: **Partial equilibrium analysis of the economic impacts of export taxes**



the domestic quantity demanded is D_1, the domestic quantity supplied is S_1 and the difference $(S_1 - D_1)$ is exported. Consider first the case of the adoption of an export tax t by a small country. When exports are taxed by t, the domestic price falls from P_1 to P_2 [2], the domestic supply falls from S_1 to S_2 and the domestic demand increases from D_1 to D_2. Hence, the single impacts of this trade policy in a partial equilibrium analysis are the following: a reduction of exports - that now equal $(S_2 - D_2)$; an increase in consumption $(D_2 - D_1)$ for domestic consumers that benefit from a lower price; a reduction in supply $(S_1 - S_2)$ by domestic producers penalised for the price fall; an increase of public revenues given by the export tax t. The benefit for consumers amounts to the area a (i.e. the change in the consumers surplus). The loss for producers amounts to the area $(a+b+c+d)$ (i.e. the change in the producers surplus). The benefit for the government amounts to the area c. The overall impact of export tax is given summing the benefits and losses. The result is a net welfare loss represented by the areas b and d [3]. However, if the policy-makers have a food security objective that implies a decrease in the domestic price, export taxes are efficient since they augment domestic consumption and reduce the local consumer price leading to an increase of the surplus of food consumers.

When the country that imposes export tax is a large country (i.e., large enough to affect world price), effects are quite similar for consumers and producers. The main differences consist of: a substantial fall of

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[2] Initially, domestic producers prefer offering their supply on the local market (untaxed) rather than on the world market (taxed). On the domestic market, supply is increased, reducing the domestic price, while the world price is unchanged. Domestic producers are hurt by this policy, as they produce and sell less at a lower price.

[3] The size of the welfare loss depends on the slope of the demand and supply curves. It means that a small exporting country is always worse off when it adopts an export tax.

world supply (since a large country is assumed to export a significant share of world exports) that pushes the world price upwards from P_w to $P*_w$; and an increase of public revenues (area e) due to the world price rise (which represents an improvement in the country's terms of trade). In this case, the implementation of this policy can lead to an increase of domestic welfare - under the usual *ceteris paribus* assumption - if the terms of trade gain exceeds the welfare loss (i.e. $e > [b + d]$). However, in terms of food security this policy measure implies a worsening because of the reduction of world food supply. [4]

2.3. Are these policy measures really effective? The empirical analyses

Some scholars state with empirical evidence that countries which imposed trade measures were effective in making domestic prices rise significantly less than those which did not intervene (see, among others, Abbott (2011); Dawe and Timmer (2012); Demeke *et al.* (2009); Jones and Kwiecinski (2010); McCalla (2009). McCalla (2009) warns against the fiscal sustainability of this kind of measures (since countries that maintain low domestic food prices as a safety net have experienced rising fiscal costs of domestic feeding programs) and emphasises the differentiated impact across countries. 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 restricted exports experienced significantly lower price increases than those who did not. From a geographic perspective, greater price stabilisation was achieved by Asian rice exporters than by 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 while China, India, and Ukraine register significant reductions of their wheat exports, the same is true for China and Ukraine for maize, and for China and India for rice.

Other scholars (Rutten *et al.*, 2013; Anderson *et al.*, 2013; Anderson and Nelgen, 2012c) highlight that if many countries adopt the same measures, these measures can turn out 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 how trade insulating measures push world

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[4] It is noteworthy that in the long run, consequences could be different if producers in the rest of the world increased their supply in response to higher prices. As a result, the price adjusts downward from the short-run level, but still remains above the pre-restriction level. Therefore, it is quite possible that export restrictions could be beneficial in the short run while having negative consequences in the long run thanks to adjustments in the terms of trade (Mitra and Josling, 2009).

food prices to even higher levels and, like 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 (as their policies will partially offset each other), and exacerbating food insecurity around the world (Martin and Anderson, 2011, 2012; Mitra and Josling, 2009). In the case of small countries these measures are likely to reduce national economic welfare too. If the country is a large country, its policy intervention will affect not only the domestic price but the international one as well leading to other distortive effects (see the previous sub-section). In their analysis on 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 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 of Africa and Asia), making them more dependent on and vulnerable to 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 be undesirable also because, collectively, they are not very effective in stabilizing domestic prices, and 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) even 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 how much the observed insulating actions of more than 100 countries in the period of 2006-2008 have affected international and domestic food prices of for 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 its apparent impact. Furthermore, they find developing countries as a group insulated more than developed countries and, as a result, parts of the price increases were "exported" to developed countries. In Martin and Anderson (2012) the authors examines the role of trade policies (particularly export and imports restrictions) as stabilization policies in the agricultural market. They state the use of these measures by all countries is ineffective in stabilizing domestic prices for the key staple foods of rice and wheat, while magnifying 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 explain 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 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 the export controls have not significantly reduced price volatility on the domestic wheat market. On the contrary, these policy measures have substantially increased market uncertainty which led to pronounced additional price volatility in the market.

This survey of the applied literature on the efficacy of trade policy distortions on food security highlights that the relationship is ambiguous and a thorough analysis of the exact channels of transmission is a complex issue. A workable solution is to investigate empirically the overall net impact of trade insulating policies on food security. This calls for appropriate methods to look at the causal effect of different treatment intensity among observations that can be considered as similar conditional to 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. It is based on the following assumptions: for each i there is a vector of covariates X_i, a ”treatment” received, $T_i \in [t_0, t_1]$ and a potential outcome, $Y_i = Y_i(T_i)$. Following Hirano and Imbens (2004) we assume: Y_i, T_i and X_i are defined on a common probability space; T_i is continuously distributed with respect to a Lebesgue measure on τ; $Y_i = Y_i(T_i)$ is a well defined random variable. For each i we postulate the existence of a set of potential outcomes, $Y_i(t)$, for $t \in \tau$ where τ is the interval $[t_0; t_1]$ referred to as the unit-level dose-response function. We are interested in the average dose-response function, across all observations i that illustrates the expected value of the outcome variable conditional to continuous treatment as follows:

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

In this exercise we use index $i = 1, ..., N$ 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 NRA in the commodity under investigations. 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, which is estimated via the following standard normal model:

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

The main purpose of estimating GPS is to create covariate balancing. However, the validity of R as a measure of similarity or dissimilarity across countries depends crucially on the validity of a set of assumptions which are standard in impact evaluation literature. First of all, the randomness of the treatment, namely the assumption of "unconfoundedness" or "ignorability of the treatment". It means in this case to avoid 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 GPS. In other words, the GPS has the following property:

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

GPS removes the bias associated with differences in covariates in three steps. In the first step, the GPS is estimated and its balancing property checked. If balancing holds, countries within GPS strata can be considered as identical in terms of their observable characteristics, independently of their actual level of treatment.[5] The validity of the balancing property should be coupled with the SUTVA (Stable Unit

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[5] Please note that as long as sufficient covariate balance is achieved, the exact procedure for estimating the GPS is of secondary

Treatment Value Assumption) condition. Notwithstanding we are dealing with some degree of heterogeneity in terms of policy coverage, the use of a standardised measure, namely the NRA which synthesises specifically the actual impact of governmental distortions, prevents the violation of the unique treatment assumptions. At the same time, working with treatment intensities prevents also any cross relationship across the various groups' outcomes in terms of food security. In order to avoid any sources of bias, however, in the aggregate case, we leave out from the empirical analysis the main importer and exporter countries.

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 the estimation of the conditional expectation of the outcome as a function of two scalar, the treatment level T and the GPS $R, \beta(t,r) = E[Y|T=t, R=r]$. The final one is to estimate the average dose-response function (DRF) of the outcome (i.e., the different dimensions of food security) averaging the conditional expectation over the GPS at any different level of NRA, as follows:

$$D(t) = E[\beta(t, r(t, X))] \tag{5}$$

Furthermore, we can estimate the varying marginal effects of the treatment by estimating the treatment effect function, which is the first derivative of the corresponding dose-response function.

4. Variables and data

In this exercise we make use of three different sets of data: i) the annual Nominal Rates of Assistance to producers (NRAs) by commodity (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 to reach a specific level of NRA (i.e., the covariates, X_i)) the outcome in terms of the various dimensions of food security ($Y(t)$). Table A.1 in the Appendix reports a synthesis of the data applied in our empirical exercise.

4.1. The treatment: the Nominal Rates of Assistance

The Anderson and Nelgen (2012c) World Bank dataset includes a core database of NRAs to agricultural industries as well as nominal rates of assistance to producers of non-agricultural tradables, together with a set of Consumer Tax Equivalents (CTEs) for farm products and a set of Relative Rates of Assistance (RRAs) which capture the extent to which domestic prices faced by farmers relative to those for producers

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importance (Kluve *et al.*, 2012).

of non-farm tradable goods have been distorted away from prices at the country's border (Anderson and Valenzuela, 2008).

NRA is defined as the percentage by which government policies directly raise (or lower) the gross return to producers of a product above what it would be without the government's intervention. 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). More specifically, NRA is computed as the unit value of production at the distorted price less its value at the undistorted free market price expressed as a fraction of the undistorted price 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 raise of domestic producers gross return (the distorted price is higher than the undistorted equivalent, because of the presence of an output support, i.e., 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). It is worth noting that NRA tends to be higher for import-competing producers than for net exporters of a specific product (Anderson, 2013). To be also noted that NRA and CTE values are identical if the only government interventions are at a country's border (e.g., a tariff on imports). The high correlation between them denotes that most policy distortions actually occur at the border (Anderson and Nelgen, 2012a).

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 - and so we need to convert the different instruments into a common metric (Cipollina and Salvatici, 2008). The WB database deals adequately with this issue 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 estimated by comparing domestic and border prices of like products (at similar points in the value chain) for each of the covered farm industries, 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 in 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).

All that considered the real added value of this updated World Bank dataset is the fact that it contains the annual values of a set of standardised measures of policy related agricultural trade distortions for a total of 75 countries (that together account for 92% of agricultural GDP) and 70 products for the overall period 1955-2010. In this exercise, because of data constraints in food security measures, we are forced to limit our dataset to the sub-period 1990-2010. Among the estimated trade distortion measures, we use here $NRAag$ for the aggregate exercise and NRA by commodity for the product level analysis (see table A.1 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). 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.

4.2. The covariates

Concerning 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 facilitate the balancing property as suggested by Dehejia and Wahba (1999) and Dehejia (2005)); the log of total population (to control for country dimension); 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 import over total exports and its squared power (to control for the level of country food dependence from abroad); the absolute percentage (positive and negative) deviations from trend in the aggregate - and of the product in question - food international prices (to control for the presence of asymmetric policy response to sizeable changes in price levels); a proxy for 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 for controlling: the status of country net exporter during a specific year; 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; and the years of food crisis (2007/2008).[6]

4.3. The outcome: the dimensions of food security

Last but not least, we should deal with the hard task to retrieve a suitable and workable measure of outcomes in terms of food security, which indeed 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.

In this paper we decide not to use a composite indicator of food security, 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 with 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 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); Pangaribowo *et al.* (2013) each dimension can be represented by a specific set of variables and indicators. Taking into account actual data availability we selected the following ones: food supply in kcal/capita/day (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.1 in the Appendix) for additional details and sources' availability. Table A.2 in the Appendix provides the summary statistics for all the variables (outcome, treatment and covariates) we use

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[6] It has to be noted that, as argued by Bryson *et al.* (2002), there is always a trade off between the increasing of 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.

in our empirical analysis.

5. Empirical results

We carried out the empirical exercise for each dimension of food security both at aggregate level and for wheat and rice in the period 1990-2010.

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, notwithstanding the high risk of misspecification due to self-selection bias between incomparable observations. Specifically, we would like to avoid the risk of endogeneity bias between food availability and trade policy, i.e., the possibility that trade policy can be influenced by the level of food availability. To this end, following Serrano-Domingo and Requena-Silvente (2013) we apply a panel model with instrumental variables. As a valid instrument we use the average level 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.

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

	OLS			**IV**		
	(1)	(2)	(3)	(1)	(2)	(3)
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's determinants[7] are highly significant and quite similar in both OLS and IV estimates. NAC coefficients in the OLS and IV models are both significant too, pointing to the consistency of both estimates. They loose significance in the IV model 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.

5.2. GPS estimation and balancing property

Regression-type analyses have a high risk of misspecification, because of self-selection bias due to incomparable observations. It is the case when the net food importer and exporter countries are more likely to adopt agricultural trade distortions during the food price spikes and/or when developing countries characterised by higher risks of food insecurity as well as the most developed countries show on average relatively higher rates of protection. To overcome this issue, we apply the GPS approach. Since the joint Jarque-Bera normality test strongly supports the null hypothesis of normal distribution of our treatment variable[8], in the first stage estimation we first regress our measure of trade distortion on a set of pre-treatment observable characteristics using an OLS approach and then estimate the GPS.

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 interpretation and statistical significance of the individual effects of the covariates are of minor importance than getting a powerful GPS (i.e., a GPS that works well in balancing the covariates by respecting the condition in eq. 3). At this purpose, 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).

Looking at the covariates individual effects, it is worth highlighting 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. The above empirical evidence is consistent with the stylised facts that richer countries tend to maintain higher protection for domestic producers, while

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[7] 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).

[8] 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				
group 2 -Asian DCs	-0.065***	0.017	-0.131***	0.039	0.019	0.033
group 3 - Latin American DCs	-0.062***	0.018	-0.075**	0.032	0.082**	0.042
group 4 - European Transition Economies	0.037**	0.019	-0.051	0.036	0.143**	0.066
group 5 - 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.

developing countries with a comparative advantage in agriculture, as well as bigger countries, tend to keep lower levels of NAC (i.e., an export protection bias). Countries characterised by high dependence from food imports with respect to their total exports tend to maintain lower levels of NAC as well since they tend to reduce the domestic prices of importables (Valdés and Foster, 2012). To be noted the asymmetry in the impacts of positive and negative deviations of international food prices from their trend. 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 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 undertake a pro-trade behaviour (Anderson, 2013; Anderson and Nelgen, 2012c,a). On a separate note, it is worth noting 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, likely because of the well known depressing impact on consumption behaviour of price volatility. 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 registered, on average and *ceteris paribus*, also during the years of "food crisis".

The first stage estimates at the product level show consistent results. The main difference stands from 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 too. In the case of rice, it is worth noting the negative sign of the per capita GDP, coupled with the positive sign of the high income countries dummy. It 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.

A further 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%). 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). As it is apparent from table A.3 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 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 lowers to 0.88 (0.98 for wheat and 0.46 for rice) and the balancing is rejected only in 3 for the aggregate case (3 for wheat and 0 for rice). Table A.4 in the Appendix reports the final group-strata structure of the data. Figs. from A.1 to A.4 in the Appendix provide a quick overview of the differences in the common support before and after GPS correction (for brevity only the aggregate case is reported).

5.3. The Dose-Response Function

The last step is to estimate a dose-response function (DRF), which illustrates, given the estimated GPS, if and how there is a causal link between NAC changes and the food security dimensions. It means to test 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. It is useful to recall that as Hirano and Imbens (2004) point out, the estimated coefficients in this regression have no direct economic meaning except that testing whether the covariates introduce any bias. While in fact 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. It means that GPS method highlights possible bias in outcomes that are actually controlled by looking over GPS strata as well as across GPS strata, 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.

Once tested our DRF at different order of the polynomial terms, as in Egger *et al.* (2012) we chose to disregard those polynomial terms that turned out to be insignificant in our OLS regression estimates. The corresponding results for the parsimonious, semi-parametric dose-response functions are summarised in tables A.5; A.6; A.7; A.8 in the Appendix. It is worth noting that also in this case R-squared is relatively high given the parsimonious specification and consistent with similar GPS empirical exercises (Becker *et al.*, 2012; Serrano-Domingo and Requena-Silvente, 2013) (lower in the wheat and rice cases).

The left panels of Figs. 3 and 4 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 right panel of the same figures represent the treatment effect function (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 estimated via bootstrapping. For brevity, all the Figures are here related to the aggregate case only (the wheat and rice cases are reported in the Appendix).

The first outcome we can derive from the DRF in the left panels of Figs. 3 and 4 is that trade insulation policies have, on average and *ceteris paribus*, a negative impact on all food security dimensions, with the relevant exception of food variability. The maximum levels of food availability, utilisation and access are associated with trade policies close to "neutrality" (when NAC is around 1.2). Specifically, if we look at the 90% confidence band, we observe that the neutrality hypothesis is not far from the region of acceptance in most of the cases when food security is, on average and *ceteris paribus*, at its maximum level. At the same time, we cannot underestimate that positive levels of NACs (between 1 and 1.2) are still significantly associated to positive food security, while the impact of higher levels of trade policy distortions (approximately for NAC higher than 1.2) are unambiguously negative in case of food availability, utilisation and access, but still positive for food stability. Please note, however, that, according to the TEFs in the right panels of the Figures the marginal impact of trade distortions on food availability, utilisation and access is negative as soon as we depart from neutrality (i.e., NAC levels different from 1), while it is positive only for food

Figure 3: DRF and TEF: the aggregate case

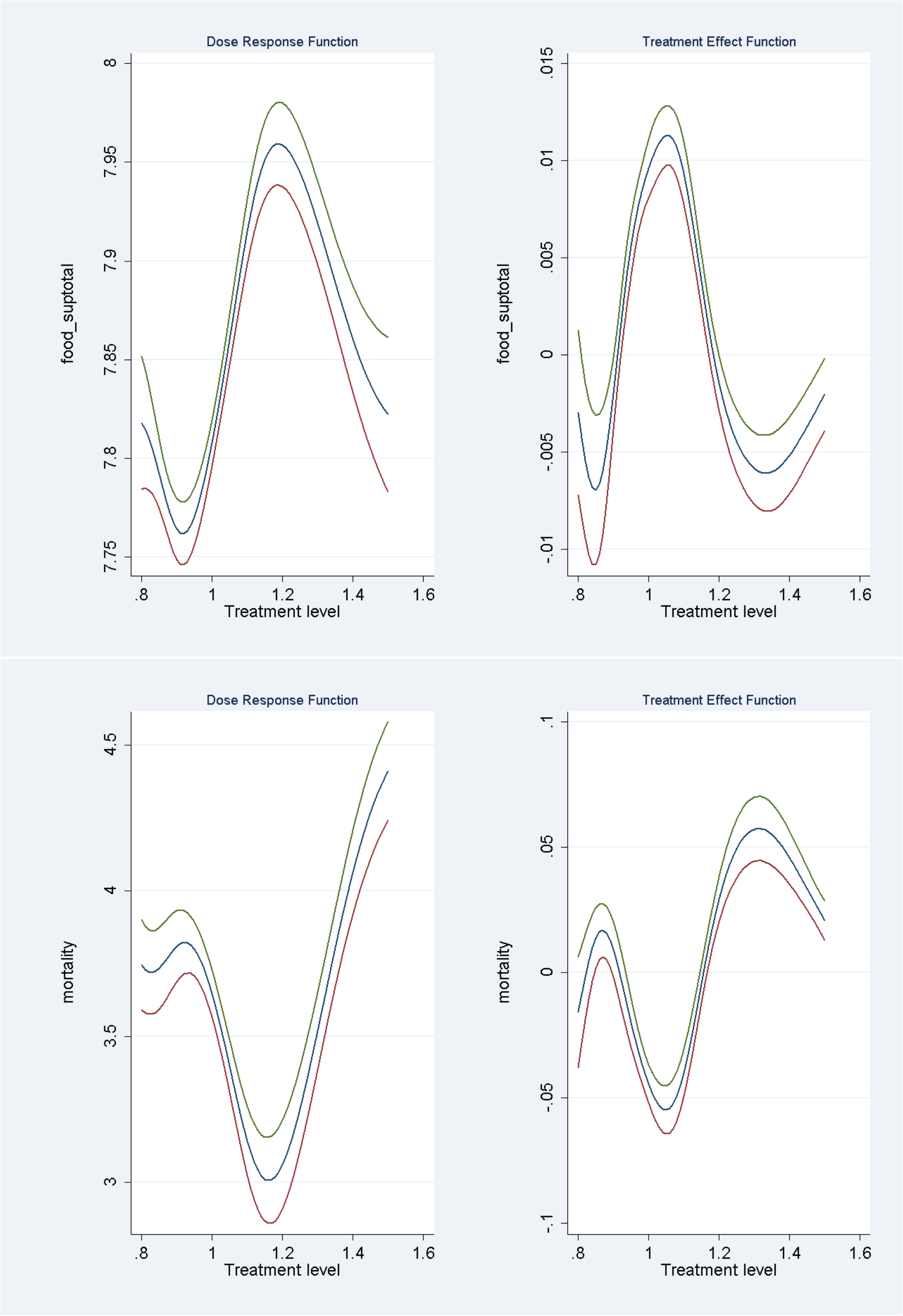
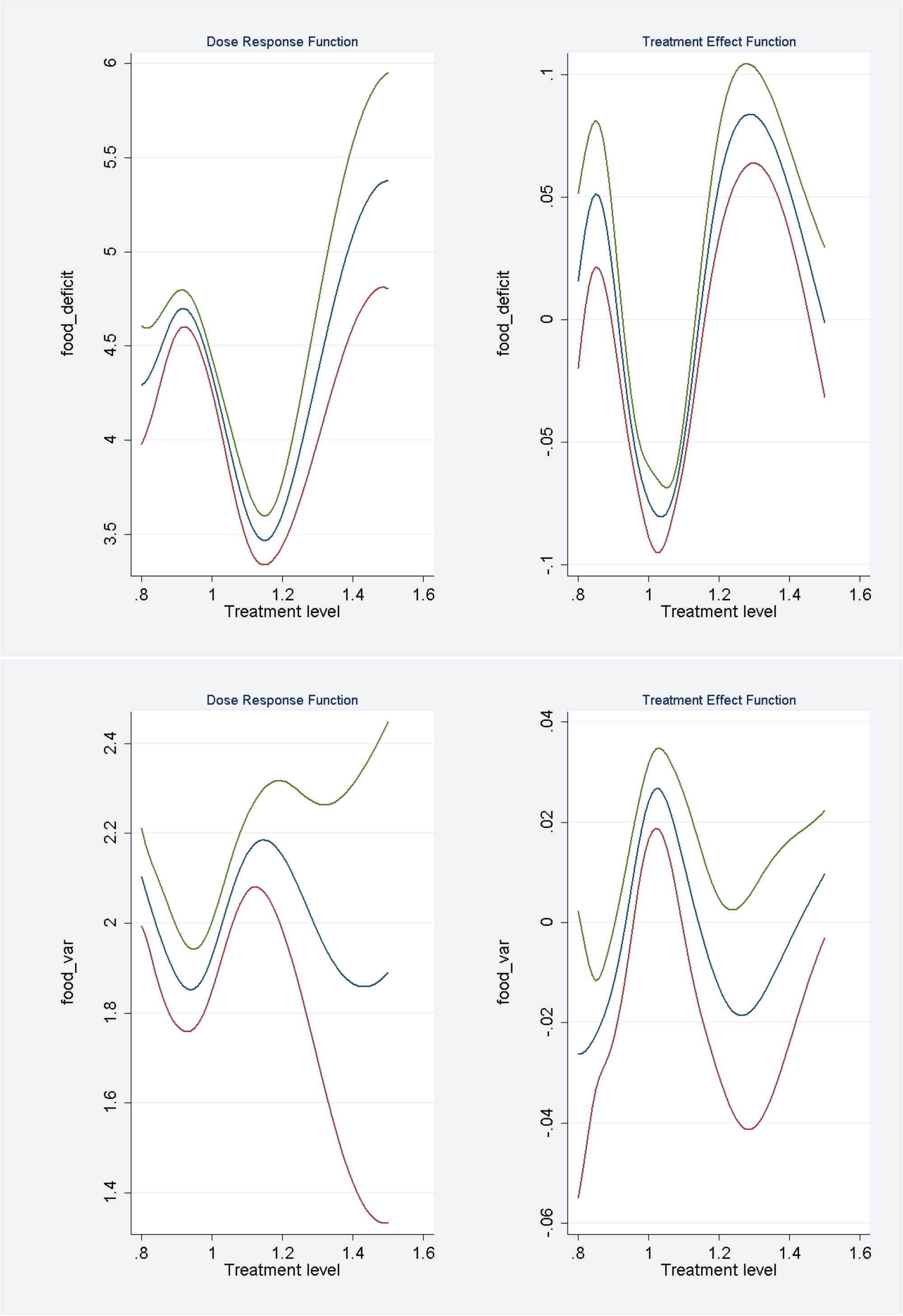


Figure 4: DRF and TEF: the aggregate case cont.d



stability.

6. Conclusions

We assessed the functional form of the relationship between trade policy insulation and various dimensions of food security, on aggregate and by commodities. We used a non parametric method for causal inference in quasi-experimental setting with continuous treatment under the (weak) unconfoundedness assumption. We 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 the empirical evidence of a significant impact of agricultural trade policy distortions on the various dimensions of food security under analysis. However, it holds on the opposite direction than hoped for by policy-makers: countries less prone to adopt trade distortion policies tend to be better off in all the dimensions of food security (food availability, access, utilisation) with the relevant exception of food stability.

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Appendix A.

Table A.1: **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)	Real per capita GDP (2005 International dollar per person).	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 (it covers food crops that are considered edible and that contain nutrients).	
	(Country) 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.	
	(Country) Net food exporter dummy.	FAOSTAT
	Regional group dummy: 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
	Food crisis dummy (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.	FAO

Table A.2: **Summary statistics of covariates**

Variable	**Mean**	**Std. dev.**	**Min**	**Max**	**Observations**
NRAag	0.130	0.263	-0.228	1.287	1072
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.3:

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

	Aggregate								**Wheat**						**Rice**					
	Prior to balancing on the GPS				After balancing on the GPS				Prior to balancing on the GPS			After balancing on the GPS			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**	**Group 1**	**Group 2**	**Group 3**	**Group 1**	**Group 2**	**Group 3**	**Group 1**	**Group 2**	**Group 3**	**Group 1**	**Group 2**	**Group 3**
lnreal pc gdp	13.921	8.091	5.536	17.173	1.957	1.120	1.373	0.506	2.572	4.708	2.102	0.760	1.459	1.810	5.007	0.552	4.450	0.284	0.580	0.567
lnreal pc gdp^2	13.993	7.770	5.064	17.485	1.906	0.999	1.338	0.385	2.534	4.717	2.149	0.808	1.477	1.863	5.011	0.826	4.162	0.291	0.610	0.592
lnreal pc gdp^3	13.984	7.405	4.570	17.681	1.852	0.867	1.293	0.265	2.511	4.708	2.163	0.853	1.487	1.904	4.972	1.085	3.848	0.299	0.634	0.613
lnreal pc gdp^4									2.499	4.683	2.151	0.893	1.490	1.932						
ln pc arable land	2.357	3.953	2.347	0.768	1.226	1.532	1.873	0.872	2.433	4.771	7.380	0.784	1.035	0.538	3.020	5.048	2.057	0.334	0.803	0.117
pos dev food prices	0.879	1.184	3.357	1.279	0.463	0.313	0.996	0.095	1.490	3.300	1.803	0.560	0.979	0.074	2.380	2.437	0.098	0.574	0.854	0.517
neg dev food prices	0.743	0.370	1.979	0.863	0.434	0.143	0.300	0.515	4.820	3.192	1.594	1.206	0.887	0.324	0.805	1.603	0.830	0.423	0.652	0.271
food price volatility	1.082	0.483	2.295	0.725	0.385	0.166	0.621	0.928	7.988	2.437	5.397	1.022	0.974	0.359	1.207	0.824	0.372	0.065	0.690	0.206
food crisis	0.307	1.045	3.146	1.784	0.130	0.405	0.613	1.542	8.915	4.255	4.397	2.136	1.556	0.714	0.225	0.289	0.070	0.060	0.111	0.265
food prod. index	6.334	6.356	4.523	8.227	0.150	1.115	1.371	1.008												
group 2 -Asian DCs	3.301	0.094	0.657	4.067	0.555	0.154	0.631	0.019	1.508	2.648	1.137	0.190	1.112	1.078	7.087	3.038	3.824	0.127	0.722	0.325
group 3 - Latin American DCs	2.397	2.836	5.058	4.609	0.007	1.361	1.693	0.084	0.809	0.114	0.698	0.393	0.066	0.112	5.917	0.379	5.545	0.708	0.801	0.901
group 4 - European Transition Economies	6.033	7.520	6.401	7.144	0.246	2.382	0.400	0.379	7.128	2.759	4.247	2.059	1.035	0.116	1.610	0.491	2.129	0.307	0.160	0.228
group 5 - High-income Countries	8.973	1.210	2.708	13.604	0.988	2.010	0.530	0.479	5.716	5.304	0.394	1.896	2.058	1.223	3.266	1.989	1.232	0.325	0.583	0.570
net food exporter	3.905	2.048	0.352	6.393	0.673	0.405	0.958	0.159	7.379	4.378	12.510	0.438	0.537	0.715	5.896	2.184	3.590	0.369	0.152	0.803
food import/total exports	5.381	6.281	4.645	7.036	1.257	1.253	1.001	0.768	0.334	4.575	4.248	0.086	1.446	1.483	0.474	1.653	1.214	0.541	0.592	0.871
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	1.656	0.661	2.330	0.549	0.207	1.333	7.186	1.775	5.258	0.109	0.250	0.911
pop^2	6.333	1.587	2.046	6.819	1.395	1.957	0.696	0.984	1.347	0.882	2.243	0.376	0.258	1.332	7.371	1.899	5.300	0.121	0.287	0.875
No. of observations	268	268	268	268	243	246	217	114	302	302	297	283	293	271	207	222	201	178	209	182
Mean t-value		4.848				0.876				3.464			0.980			2.740			0.457	

Note: All time variant variables with one lag

Table A.4: **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

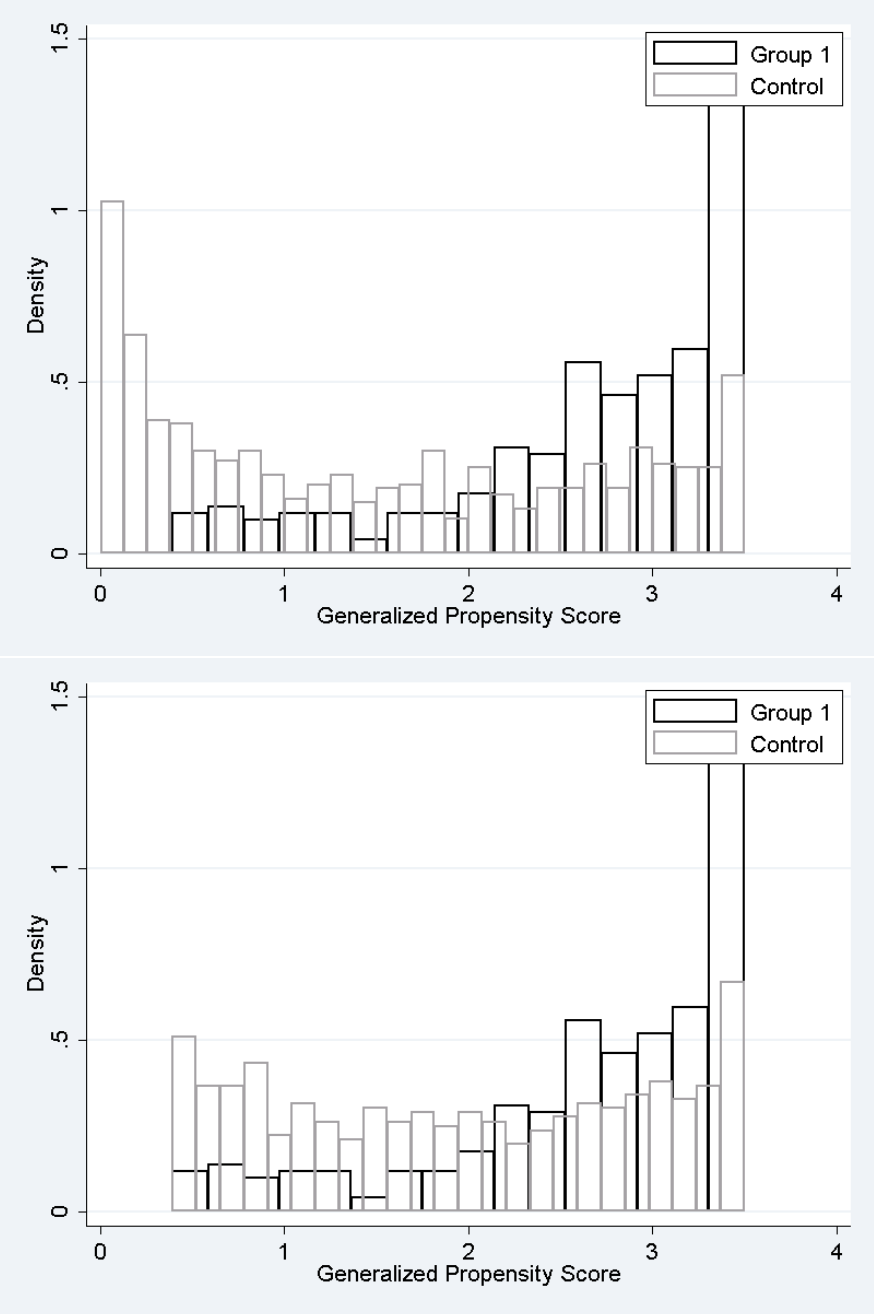
Wheat

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

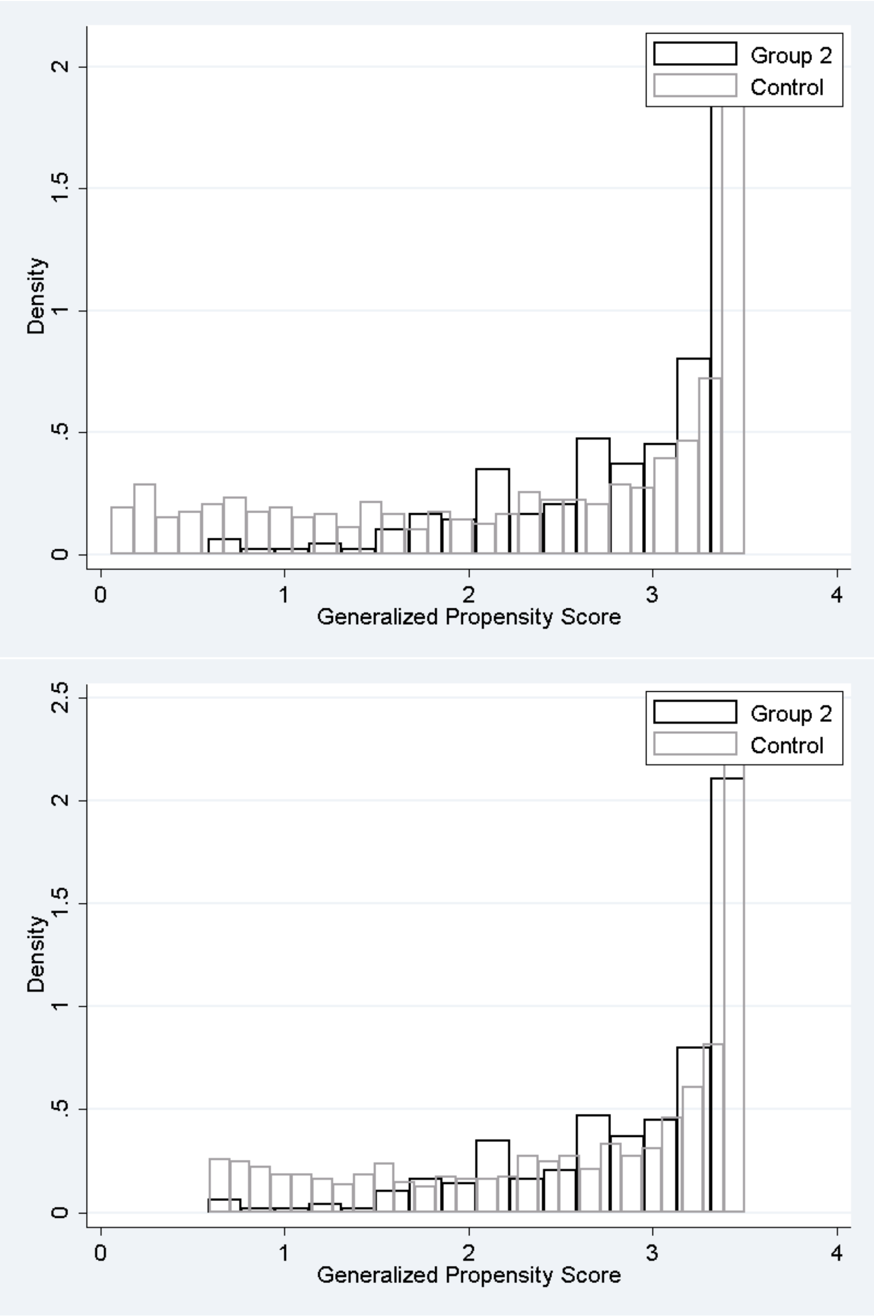
Strata	Control1	Group1	Control2	Group2	Control3	Group3
1	128	18	104	21	100	19
2	70	18	46	21	47	18
3	40	18	31	21	80	18
4	39	18	38	21	58	18
5	39	18	23	21	30	18
6	49	18	26	21	27	19
7	14	18	19	21	25	18
8	5	18	28	21	12	18
9	5	18	23	21	3	18
10	2	17	23	20	5	18

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



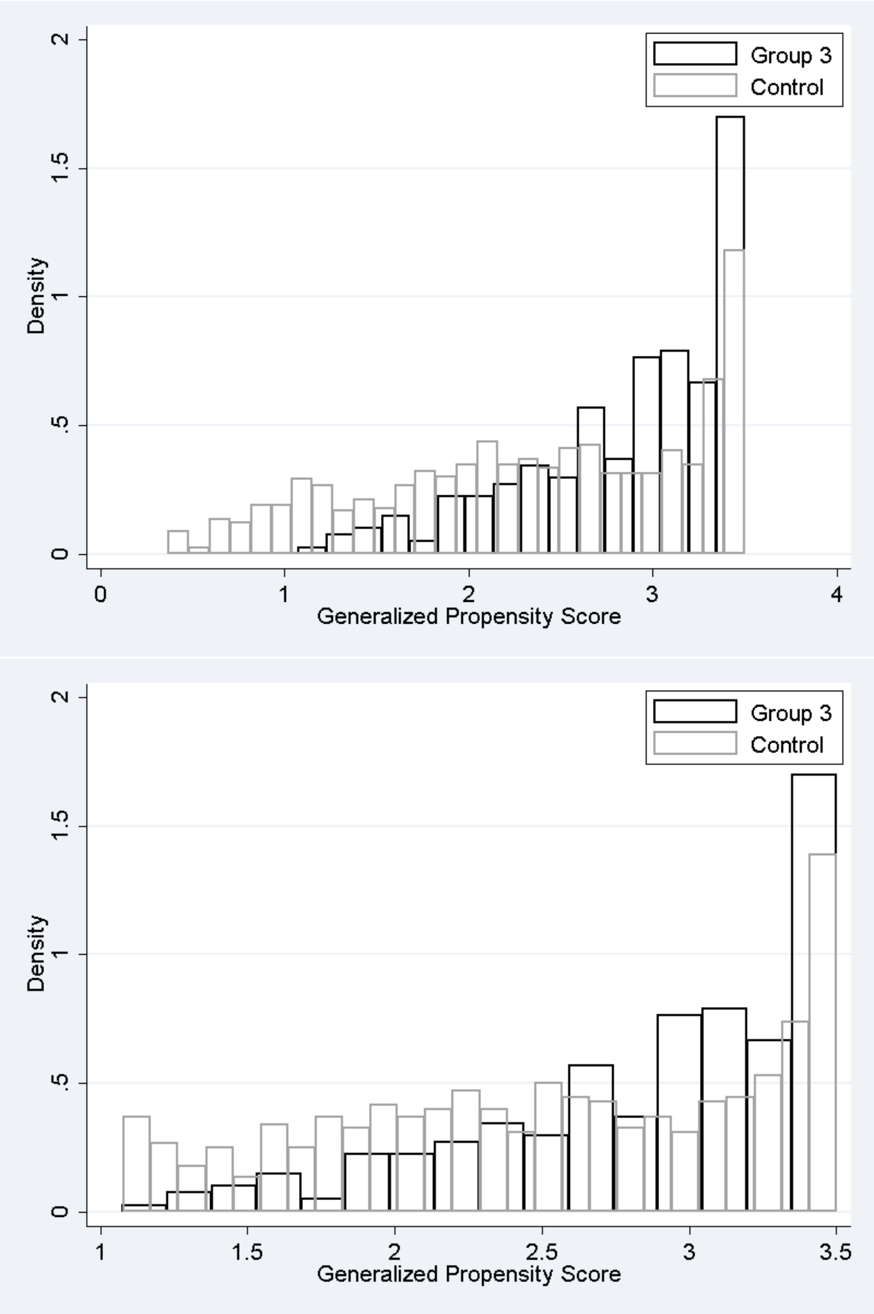
Source: Authors' calculations

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



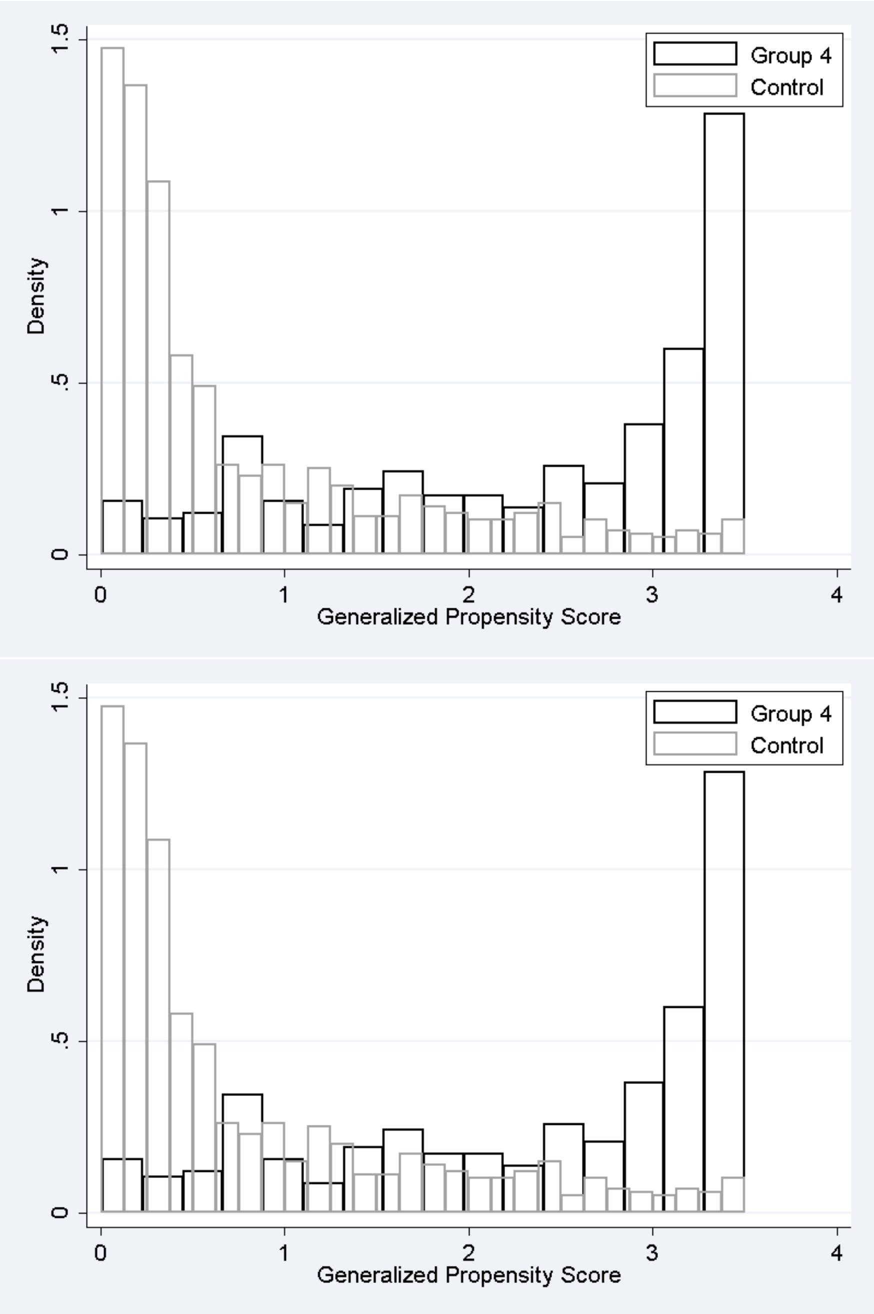
Source: Authors' calculations

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



Source: Authors' calculations

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



Source: Authors' calculations

Table A.5: **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.6: **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.7: **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.8: **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.5: DRF and TEF: the wheat case

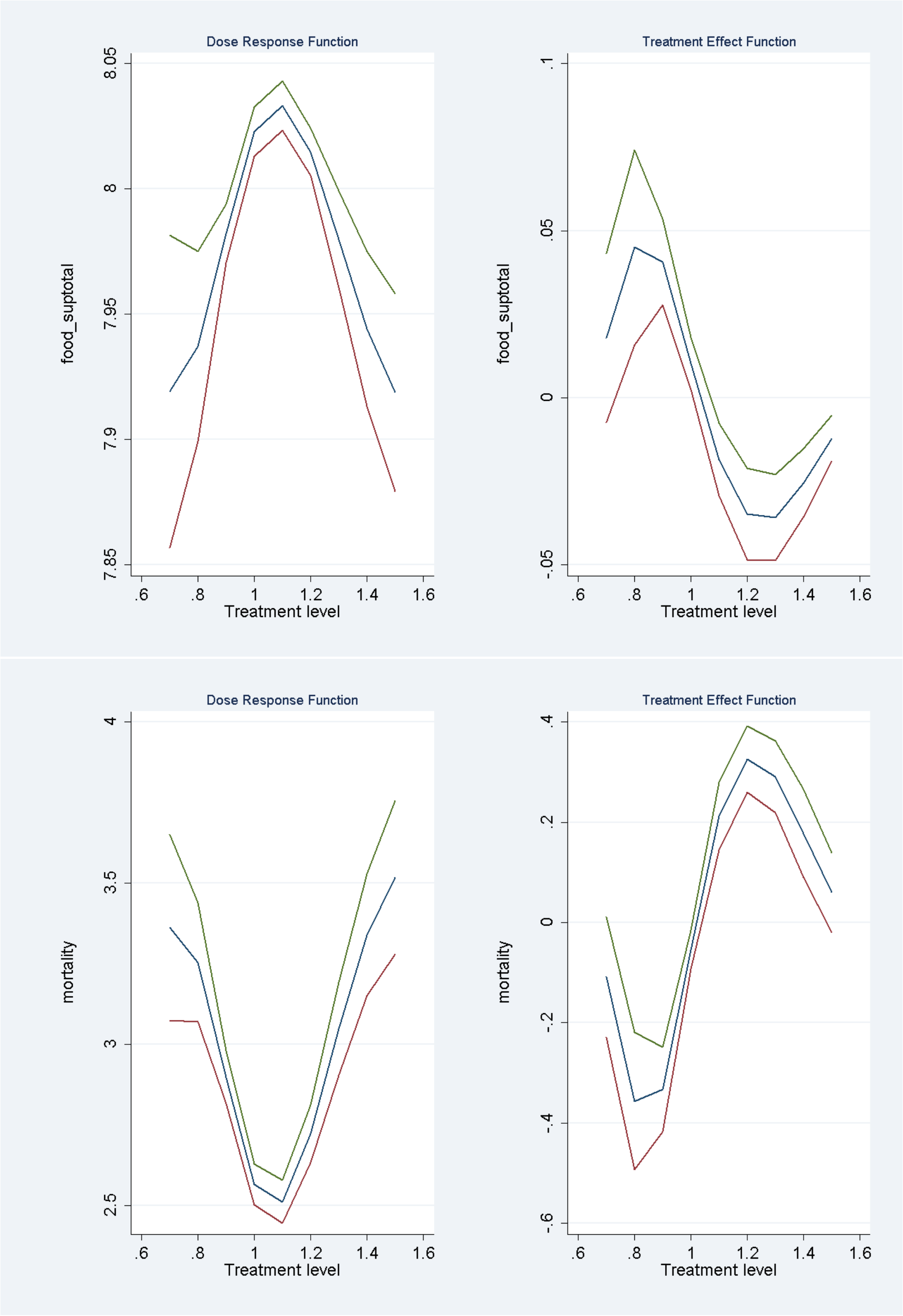


Figure A.6: DRF and TEF: the wheat case cont.d

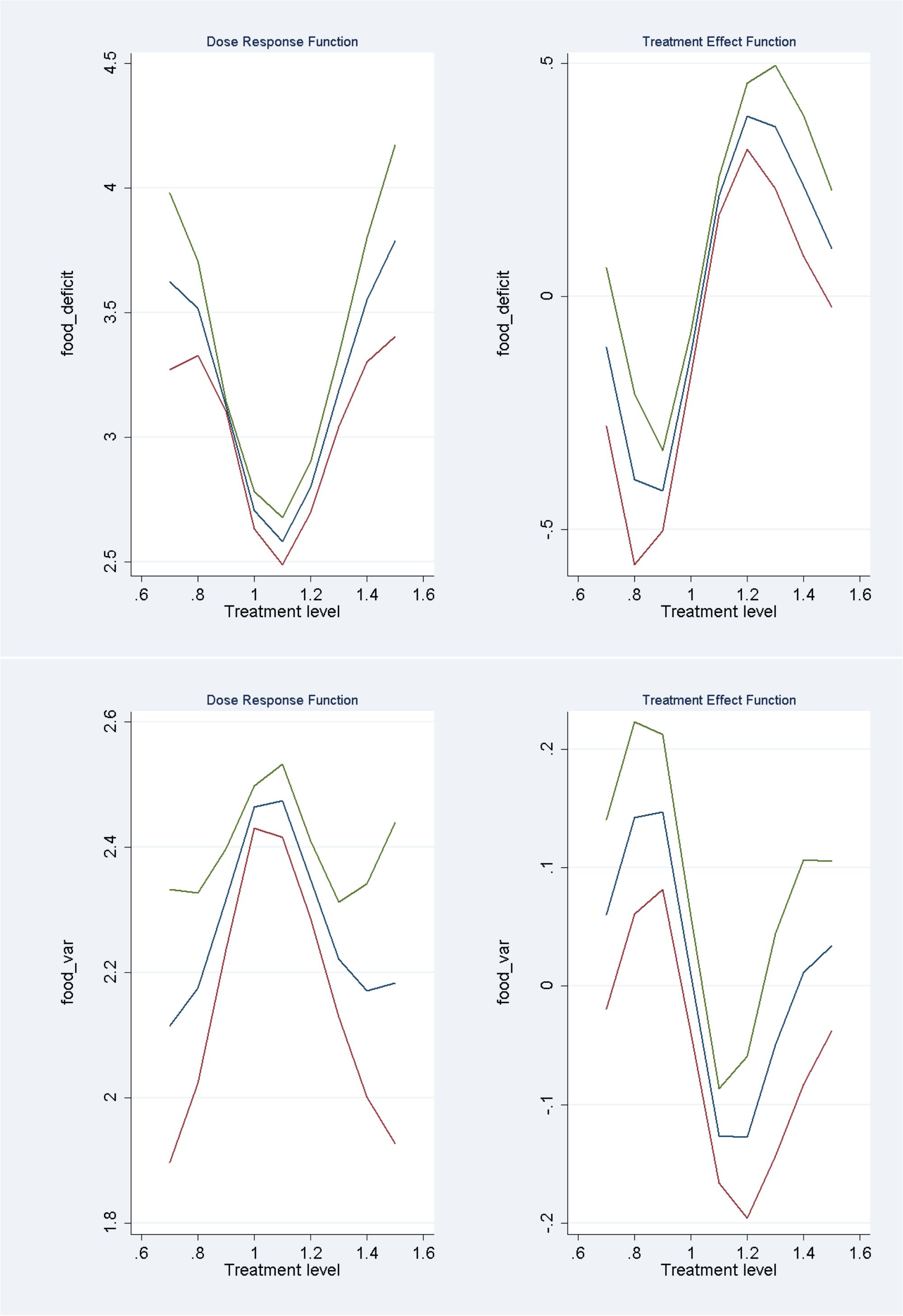


Figure A.7: DRF and TEF: the rice case

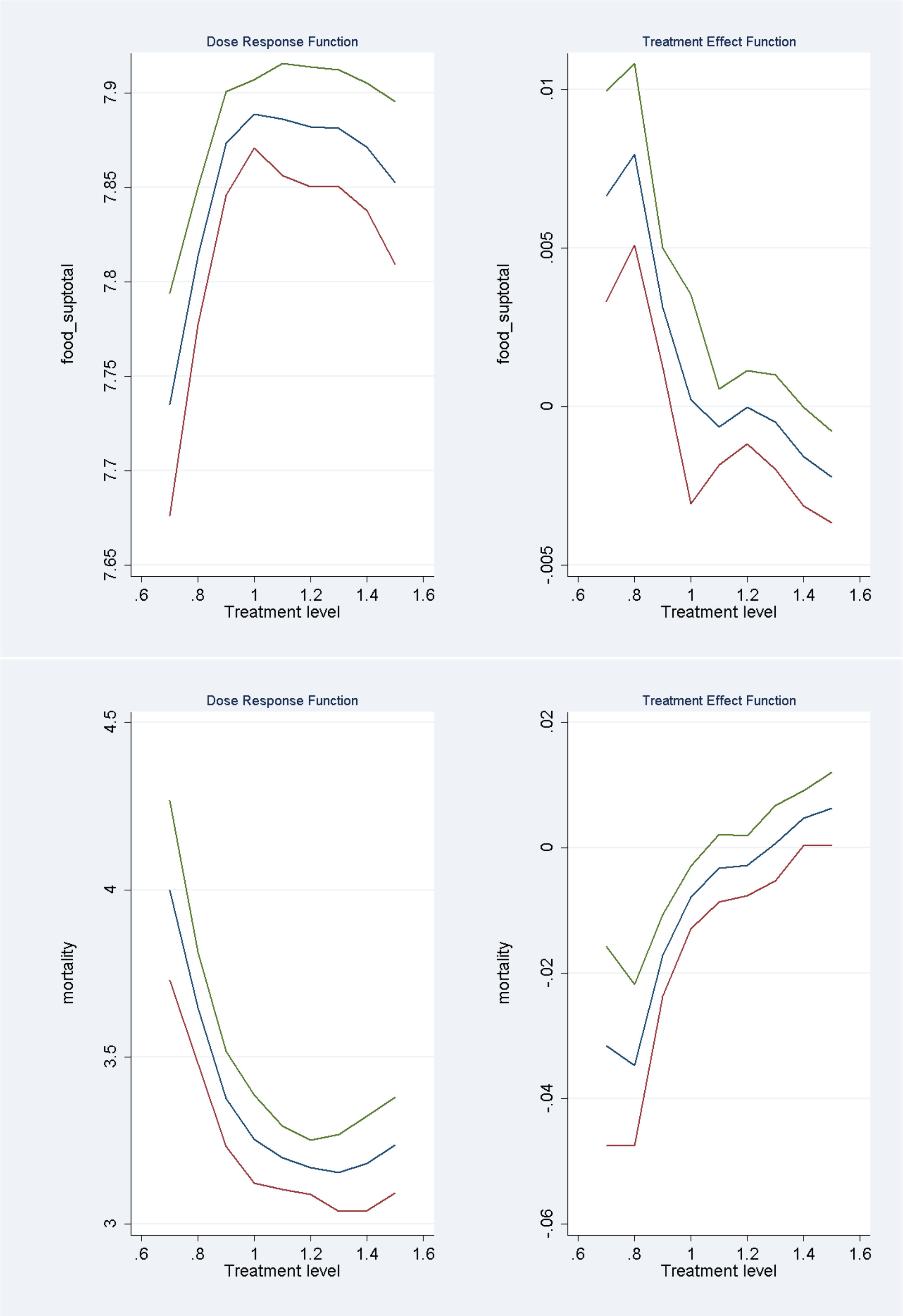


Figure A.8: DRF and TEF: the rice case cont.d