Welfare Effect of Urea Deep Placement (UDP) Technology Adoption among Smallholder Rice Farmers in Kwara State, Nigeria – Analysis of a Randomized Control Trial Experiment[1]

By

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Abstract

We analyse the effects of adoption of urea deep placement (UDP) technology on household welfare using household data collected through a randomized control trial experiment conducted among rice farming households in Kwara State, Nigeria. In order to adjust for unequal sampling fractions and correct for possible misspecification and selection bias in the effects model, we estimate a treatment effect model using the doubly robust inverse probability weighted regression adjustments. The results show that variable that enhances intra-household joint decision-making on farm input use and wealth indicators encourage UDP adoption while physiological risks tend to discourage adoption. Differential use of food consumption coping strategies exists between adopters and non-adopters along less severe but not severe strategies. We find that UDP technology can significantly increase food security, measured as food consumption coping strategy index, among adopting households. This implies that the technology is welfare increasing, and its adoption could be discouraged by health and production – related risks interventions.

Keywords: Rural household welfare, Urea deep placement (UDP), Randomized control trial, Food consumption coping strategy index, inverse probability weighted regression adjustment, Nigeria

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1. Introduction

Exponential population increase, climate change effects, conflicts, and soil nutrient depletion put much pressure on food and fiber supply under limited supply of land, water and other agricultural production inputs (Campbell *et al*., 2014). Increasing food production and ensuring food security would therefore require that farming systems consider the need to meet both the present and future food and fiber needs of the population. This can be achieved by either expanding the areas under cultivation, including bringing previously uncultivated areas under production or by intensification. The later strategy is increasingly becoming acceptable as a better alternative to agricultural area expansion because of its response to land pressure; and its potential to boost agricultural productivity and household welfare with less negative impacts on the natural resource base (Stone, 1994; Vanlauwe *et al.*, 2014; Nin Pratt, 2015). Thus, current research and policy options for productivity increase have been centered on environmentally sustainable input intensification technologies (Liverpool-Tasie *et al.*, 2015).

In agricultural landscape, intensification is defined as "producing more units of outputs per units of all inputs and through new combinations of inputs and related innovations" (The Montpellier Panel Report, 2013). Often achieved through greater investments of capital or labour, and higher use of fertilizer or pesticides, the Report noted that agricultural intensification is aimed at increasing farm productivity. Furthermore, increase in yield under agricultural intensification can be achieved via the use of more improved inputs which usually have higher productivity potential, and/or through precision application technologies like in the cases of fertilizer and water applications. Precision application and adherence to recommended production practices ensure higher productivity per hectare while decreasing the quantity of production inputs used and costs incurred. This type of intensification strategy is evidenced in Liverpool-Tasie *et al*. (2015).

Although agricultural intensification is necessary to ensure sustained food supply, the types which take environmental issues into consideration through more efficient use of inputs have been advocated in recent years (Snyder and Cullen, 2014). Hence, the concept of sustainable agricultural intensification is premised on the utilization of existing land area to produce more food without compromising future production. As Blum *et al*. (2014) defined it, sustainable intensification is the "simultaneous improvement in the productivity and environmental management of agricultural land". Broadly, sustainable agricultural intensification is defined as increasing agricultural yield from existing land area in such a way that negative environmental impacts are reduced and contributions to natural capital and flow of environmental services to ensure continued future production are assured (Garnett *et al*., 2013; Campbell *et al*., 2014).

In countries like Nigeria where the intensity of use of such production inputs as fertilizer is still low, this concept provides the opportunity to advocate for increased use in the right quantity and method that would minimize the future negative effects it might engender on the environment.

From the above definitions, agricultural and environmental outcomes form the foci of sustainable agricultural intensification. As agricultural outcome, sustainable intensification targets increased farm productivity per hectare through improvement in use efficiency of such inputs as fertilizers, agrochemicals (herbicides and pesticides), water and machinery. Though the identified inputs are vital for increased food production when used in addition with improved seeds, they pose great threat to the environment when inappropriately applied. Hence, the focus is often on efficiency rather than intensity of use under sustainable intensification (Blum *et al*., 2014). It is, therefore, a path to improved household welfare since increase in farm production per unit input, in addition to fair and efficient market, ensures that households' income is increased. Extra farm income for farmers has the potential to encourage the purchasing and consumption of nutritious foods, investment in household education, access to quality healthcare services, better social inclusion, and improved standard of living. While achieving the agricultural outcome, sustainable agricultural intensification also looks to positively influence the environmental outcomes – nutrient utilization such as nitrogen uptake and fixation and the preservation of critical ecosystem services for increased output per hectare of environmental services of the farm – which affect the supply sides of the food system (Blum *et al*., 2014). In the light of these outcomes, sustainable agricultural intensification is literally aimed at enhancing household welfare through increased farm productivity.

Studies (DFID, 2003; Oseni *et al*., 2014) indicate a direct relationship between agricultural productivity and welfare change. These studies show that a one percent increase in agricultural productivity has the potential of reducing extreme poverty by between 0.3 and 2 percent. This follows that in addition to agricultural productivity increase due to the adoption of intensification technologies, the centrality of adoption would be on how it translates to improved welfare, particularly the food security level of the farming households. Assessing such implications, it is necessary to know the extent of agricultural enhancement of the poor (Afolami *et al*., 2015) can serve as an incentive to promote intensification technologies among farming households. In contrast to the numerous studies explaining the effect of technology adoption (improved seeds, irrigation etc.) on farm productivity, and household welfare in Nigeria (Awotide *et al*., 2012; Obisesan, 2014; Afolami *et al*., 2015), the literature investigating the effect of environmentally sustainable input intensification technology like the Urea Deep Placement (UDP) technology on Nigeria smallholder farmers' welfare remains scanty.

The significance of this paper to literature is, therefore, twofold: first, it contributes to the scarce empirical evidence that shows how the adoption of a productivity-enhancing and environmentally sustainable technology (Urea Deep Placement) translates to welfare improvement of rural households, especially in Nigeria. Second, this study is the first agricultural technology adoption – welfare linkage study in Nigeria (to the best of our knowledge) that employs data collected through a robust experimental approach of the randomized control trial (RCT). This methodology solves the endogeneity and selection bias problems associated with the usual impact evaluation techniques, and ensures internal validity by randomly assigning the respondents into treatment and control groups before the intervention starts.

The rest of the paper is organized as follows. Section 2outlines the key features of urea deep placement technology. In section 3we describe the data and methods used in the analysis, and this is followed by results and discussion in section 4. The final section concludes the paper.

2. Overview of Urea Deep Placement (UDP) technology

In rice production, nitrogen fertilizers provide the most essential nutrient – Nitrogen (N), which enhances the crop's vegetative growth and development, and yield (Naznin *et al*., 2014). Conventionally, nitrogen fertilizers come as prilled urea and are applied by farmers through broadcasting. This method of application coupled with high application rates and poor timing of application has been adjudged inefficient due to the significant loss of nitrogen through volatilization, denitrification, leaching, and runoff, resulting in both economic loss and environmental hazards (Savant and Stangel, 1998). About two-third (2/3) of the broadcast nitrogen is usually lost through these processes, leaving only one-third of the nitrogen fertilizer for plant use. This huge loss usually prompts farmers to do one or more topdressing within the period from transplanting to flowering (Liverpool-Tasie *et al*., 2015; Vargas, 2012).

The Urea Deep Placement is an innovative fertilizer deep placement (FDP) technology developed to address the improper use of urea fertilizers and to encourage increased nitrogen use efficiency at farm level while reducing the environmental hazards associated with broadcasting method (Rahman and Barmon, 2015; Liverpool-Tasie *et al*., 2015). It consists of two components, namely, urea briquetting and placement of briquettes below the soil surface. Urea briquetting process involves compressing prilled or granular urea into individual "lumps" which varies between 1.8 and 2.7 grams in weight (Tarfa and Kiger, 2013; Savant and Stangel, 1998). These individual “lumps” are usually referred to as urea super granules (USG). The deep placement of the USG below the soil surface uniquely identifies the technology as the best solution for increased nitrogen use efficiency and environmental sustainability. When properly placed, the USG slowly makes nitrogen available throughout the life cycle of the crop plant and as such, top dressing is not required. The technology performs optimally when rice seedlings are raised in a nursery incorporated with NPK fertilizer and transplanted at 2 – 3 weeks old into well puddled and levelled field. Also, the rate of nutrient availability and utilization is enhanced when transplanted rice fields are well watered 2 -3 days after the application of the USG.

Studies have identified the potential of this technology for productivity increase. In Nigeria for instance, studies (Tarfa and Kiger, 2013; Liverpool-Tasie *et al*., 2015) show that the use of the urea deep placement technology increased rice productivity by 20 – 30% with about 40% increase in nitrogen use efficiency over the traditional broadcasting method. In Bangladesh, the experimental trials of NPK briquette deep placement on vegetables resulted in about 15% - 37% yield increase with a 10% decrease in the quantity of nitrogen applied (Choudhury *et al*., 2015).

3. Data Description

Data for this study originates from a survey of 1171 farming households from 60 randomly sampled villages in two local government areas (LGAs) (Edu and Pategi) in Kwara State, Nigeria. The randomized control trial experimental design survey was conducted by the Nigeria Strategy Support Program of the International Food Policy Research Institute (NSSP – IFPRI) and Michigan State University (MSU) as part of a joint project under the “*Guiding investments in Sustainable Agricultural Intensification in Africa* (GISAIA)”. The study area has significant potential for yield increases among rice farmers, whose yield is about 2.8 tons/ha (NAERLS, 2013).

Following the randomization of the 60 villages into 45 treatment and 15 control villages, a baseline survey involving a total of 1185 households was conducted between January and February 2014. Within the 45 treatment villages, the treatment process took place during the pre-planting and planting period, between June andJuly 2014. It started with the selection of village promoters and the establishment of demonstration plots prior to the 2014 planting season. This was followed by field days held in each treatment village during which further information about the UDP technology were disseminated via the village promoters. Within treatment villages, guaranteed supply of the urea super granules (USG) was provided through Notore[3] field agents throughout the rice planting season. In control villages, no Notore intervention was permitted over the study period. The previously sampled households were re-interviewed on the same types of information during post-harvest season in January 2015 after the main rice harvest period. In both interviews, detailed self-reported individual and household level data such as use of urea super granules, socio-economic characteristics, food consumption coping strategies, shocks, among others, were collected. In what follows, we consider households to be 'UDP households' if they reported having used USG fertilizer during the 2014 cropping year. The follow-up survey allows for analysis of inter-annual household dynamics. However, our analysis is based on a balanced panel of 1, 046 farming households.

[3] Notore is a Nigeria-based private fertilizer manufacturing company.

4. Methodology

4.1. Outcome variable

Indicators of food (in)security levels provide for the understanding of welfare status of individuals or households. Notable among these food security indicators are the coping strategy measures which capture the short-term food sufficiency elements of food security at household level (Maxwell, 1996). According to Maxwell *et al*. (2008), the coping strategies are used to investigate household behaviours in the face of food shortages and when faced with financial constraints. These behaviours fall into several recognized categories: those that change dietary intake; those that increase, even by unsustainable means, the amount of food available at the household level; those that reduce the number of people to provide for; and those that ration food or manage the shortfall (Maxwell *et al*., 2008). Household responses to the consumption coping strategy questions are usually combined into a score known as the household coping strategy index (CSI), which is a measure of household food security status (Maxwell *et al*., 1999). The uniqueness of this indicator lies in its ability to query household behaviours directly and factor in the severity of different behaviours, and consequently, captures the notion of food adequacy and vulnerability. Again, it is devoid of the usual bias and cost implications associated with the objective measures of welfare. Its flaws include those associated with contextual differences which make comparison across households and localities difficult, biased results from misreporting, and the tendency of the index to underreport the number of severely food insecure households (Maxwell *et al*., 2003). Variants of the coping strategy index have been identified and include the full context-specific coping strategy index (FCSI) and the reduced coping strategy index (RCSI). The former uses a set of coping strategies that are location-or group-specific with a focus on localized food security situations, while the later uses five of the coping strategies in the full context-specific index to assess household food security situation. These five strategies are considered “standard coping behaviours” which can be employed by households anywhere. Each has a universal severity weighting. Their index, which reflects household food security status as the full context-specific coping strategy index, can be used to compare household food security across different context (Maxwell *et al*., 2003). The five food consumption coping strategies used for the construction of the reduced coping strategy index and their universal weighting are as follows:

- Relying on less preferred foods (1.0);
- Limiting the portions at mealtime (1.0);
- Reducing the number of meals per day (1.0);
- Borrowing food/money from friends and relatives (2.0); and
- Restricting consumption by adults in order for small children to eat (3.0)

Using the above, the RCSI for each household is calculated using:

$$RCSI_h = \sum csf_i * w_i \quad (1)$$

Where $RCSI_h$ = reduced consumption coping strategy index for household, h; csf_i = relative frequency of coping strategy, i, used by household per week; and w_i = universal weighting.

4.2. Randomized control trial framework for impact evaluation of Urea Deep Placement adoption

The objective of this study is to estimate the effect of UDP adoption on household food security status, an indicator of welfare, measured by the average treatment effect on the treated (ATT). Let A_i represents the adoption status of households such that A_i =1 if households used urea super granule (USG) and A_i =0 if households did not; and W_i denotes the household's welfare level. Following Takahashi and Barrett (2014), the average treatment on the treated (ATT) is the average difference in outcomes of rice farmers who adopted the UDP technology and those who did not:

$$ATT = E(W_{1i} - W_{0i} \mid A_i = 1) = E(W_{1i} \mid A_i = 1) - E(W_{0i} \mid A_i = 0), \quad (2)$$

where $E(.)$ denotes an expectation operator, W_{1i} is an outcome of interest for household i that used urea super granules (USG) in rice production, W_{0i} is the outcome of the same rice farming household had it not used USG in rice production, A_i is the treatment indicator equals to 1 if the household adopted the UDP technology, and 0 otherwise, and statistically independent of welfare outcomes (W_{1i}, W_{0i}) of the household, which guarantees that ATT is estimated by a difference in sample means and the estimator is unbiased, consistent and asymptotically normal in a randomized treatment setting (Wooldridge, 2002).

However, self-selection into treatment is still expected to occur under randomization since an individual's decision to adopt the technology might be dependent on the benefits of the technology, $(W_{1i} - W_{0i})$. As such, estimating equation (2) by just comparing the outcomes between adopters and non-adopters will likely yield biased estimates, expressed by:

$$[E(W_{1i} \mid A_i = 1) - E(W_{0i} \mid A_i = 0)] = ATT + [\,E(W_{0i} \mid A_i = 1) - E(W_{0i} \mid A_i = 0)] \quad (3)$$

The left-hand side of equation (3) measures the average difference in outcome between actual UDP adopters and non-adopters, while the last term of the right-hand side indicates the magnitude of bias from the true ATT due to differential outcomes between UDP adopters and non-adopters in the absence of UDP technology (Takahashi and Barrett, 2014; Liverpool-Tasie *et al.*, 2015). Although the assignment of households to treatment and control groups in this study is random, household's UDP adoption decision is not leading to selection bias.

We use the doubly robust inverse probability weighted regression adjustments (IPWRA) estimator with added controls to account for the selection bias and to consistently estimate the ATT outcome under the conditional independence assumption. The IPWRA is commonly used to adjust for unequal sampling fractions and biases due to restriction of analysis to complete cases (Seaman and White, 2011), correct for possible misspecifications in the effects models, and obtain consistent estimates in the presence of sample-selection (Wooldridge, 2007). Also, adjusting for covariates further removes biases (Athey and Imbens, 2016). Equation (3) is, therefore, estimated as:

$$[E(W_{1i} \mid A_i = 1) - E(W_{0i} \mid A_i = 0)] = [E(W_{1i} \mid X_i,\ A_i = 1) - E(W_{0i} \mid X_i,\ A_i = 0)] \tag{4}$$

where X_i are baseline covariates of the households.

4.. Results and Discussion

4.1. Socio-economic and plot characteristics

Table 1: Summary of baseline sample households' socio-economic and food security characteristics

Characteristics	**All sample Mean**	**Village type** Control	Treatment	**P-Value**
Food consumption coping strategy index (FCCSI)	4.04 (0.19)	4.45 (0.39)	3.90 (0.22)	0.21
Gender of household head (male = 1)	0.99 (0.00)	0.98 (0.01)	0.99 (0.00)	0.02**
Age of household head (Years)	43.56 (0.42)	45.30 (0.82)	42.97 (0.48)	0.02**
Years of schooling of household head	5.89 (0.18)	6.14 (0.37)	5.79 (0.21)	0.41
Household size (Number)	7.36 (0.11)	7.41 (0.21)	7.34 (0.13)	0.79
Household dependency ratio[4]	1.13 (0.02)	1.14 (0.05)	1.13 (0.03)	0.87
Civil status of household head (with spouse = 1)	0.97 (0.01)	0.95 (0.01)	0.97 (0.01)	0.26
Net non-farm income (₦)	27098.84 (3359.96)	19825.45 (4117.83)	29566.76 4275.35)	0.21
Number of plots owned	2.86 (0.04)	2.80 (0.08)	2.88 (0.05)	0.46
Staples cultivated by household (Yes = 1)	0.96 (0.01)	0.97 (0.01)	0.96 (0.01)	0.36
Tubers cultivated by household (Yes = 1)	0.29 (0.01)	0.24 (0.03)	0.31 (0.02)	0.02**
Pulses cultivated by household (Yes = 1)	0.25 (0.01)	0.22 (0.03)	0.26 (0.02)	0.23

[4] The overall age dependency ratio is defined as the sum of the population aged 0 to 14 years and 65 years and above divided by population aged 15 to 64 years.

Vegetables cultivated by household (Yes = 1)	0.27 (0.01)	0.28 (0.03)	0.26 (0.01)	0.58
Other crops cultivated by household (Yes = 1)	0.003 (0.002)	0.004 (0.004)	0.003 (0.002)	0.75
Plot characteristics				
Farm size (Ha)	2.38 (0.06)	2.29 (0.13)	2.41 (0.07)	0.39
Use improved seed (Yes = 1)	0.33 (0.01)	0.29 (0.03)	0.35 (0.02)	0.09*
Use tractor (Yes = 1)	0.47 (0.02)	0.46 (0.03)	0.47 (0.02)	0.63
Use agrochemicals (Yes = 1)	0.71 (0.01)	0.69 (0.03)	0.72 (0.02)	0.35
Irrigation use (Yes = 1)	0.12 (0.01)	0.12 (0.02)	0.12 (0.01)	0.79
Effect of shocks experienced				
Climate-related (Yes = 1)	0.41 (0.02)	0.45 (0.03)	0.39 (0.02)	0.09*
Health-related (Yes = 1)	0.28 (0.01)	0.28 (0.03)	0.28 (0.02)	0.97
Market-related (Yes = 1)	0.14 (0.01)	0.12(0.02)	0.14 (0.01)	0.36
Pest/disease-related (Yes = 1)	0.10 (0.01)	0.10 (0.02)	0.10 (0.01)	0.98
Socio-political-related (Yes = 1)	0.07 (0.01)	0.08 (0.02)	0.06 (0.01)	0.26
Number of observations	**1, 046**	**265**	**781**	

Source: Authors' calculation based on Kwara State UDP Technology Adoption Data, 2015.
**, * Significant at 5% and 10%, respectively; Standard errors in parentheses

The results in Table 1 show that both groups show similar characteristics except for gender, age, tuber crop cultivation, use of improved seeds, and the effect of climate-related shocks where there are significant differences between the two group. Overall, the households are mostly male-headed (99%) with average age of 44 years and 6 years of completed education. Most household heads live with their spouses (97%), and have relatively large sizes with an average of 7 persons and a dependency ratio of 1.13. The proportion of tuber farming households and the use of improved rice seed are significantly higher among treatment compared with control households. The economic effects of climate-related shocks experienced by household tend to be higher among households in the control than treatment group. There is no significant difference in the food consumption coping strategy index of treatment and control households. However, the index is lower for treatment (3.90), an indication of better food security level, compared with the control (4.45) households. Most of the households use agrochemicals (71%), and tractor (47%) in their farming operations, while irrigation is less common (12%). On average, households own about 3 farm plots of about 2 hectares in size. While most of the households (41%) are affected by climate – related events and 28% affected by health-related events, only 7% of the households were affected by socio-political incidences in the villages.

4.2 Changes in food (in)security status of households in the study area

Table 2 displays the proportion of households that used the different food consumption coping strategies at least once in the seven days preceding each interview period. Results show that households in the study area experienced some form of food insecurity, which is significantly higher at baseline (pre-harvest) than at endline (post-harvest) period. Again, higher proportion of the households used the more of the less severe food consumption strategy to cope with household food inadequacy. These less severe measures are likely to be exhausted by households before they opt for the severe strategies, which signify the peak of food insecurity. In the order of decreasing proportion of households, the most widely used strategies are reliance on less preferred foods (89%), limiting the variety of foods eaten (82%), and limiting portion size (59%) with the proportion of households that used these strategies being significantly lower at endline. At baseline for instance, 100% of the households relied on less preferred foods at least once in a week when they face food shortages compared with 77% who used it at endline. Similarly, 95% of the households opted to limit the variety of food eaten while 69% used the strategy at baseline and endline, respectively. Social networks appear to play significant role in situations of food shortage in the household. In event of food inadequacy, 22% of the households borrow food, or rely on help from friends and relatives to smoothen their consumption, with more (31%) households doing so at least once a week at baseline than at endline with 13%. Overall, the percentage reduction in the use of the most severe strategies during the endline period is greater than 50%, indicating an almost inexistent severe food insecurity situation. Using a nationally representative dataset, Edeh and Gyimah-Brempong (2015) found a similar trend in the use of these severe food consumption coping strategies among rural households in Nigeria.

Table 2: Changes between baseline and endline households' food consumption coping strategies (number of days per week) in the study area

Category of Strategy	Food Consumption Coping Strategy Used (Food security dimension)	Pooled data	Baseline	Endline	Sig. of mean difference
Less Severe	Rely on less preferred foods (acceptability)	**0.89** (0.03)	**1.00** (0.05)	**0.77** (0.04)	***
	Limit the variety of foods eaten (quality/diversity)	**0.82** (0.03)	**0.95** (0.04)	**0.69** (0.04)	***
	Limit portion of size at meal-times (quantity)	**0.59** (0.02)	**0.75** (0.04)	**0.43** (0.03)	***
	Reduce number of meals eaten in a day (quantity)	**0.39** (0.02)	**0.52** (0.03)	**0.26** (0.02)	***
	Restrict consumption by adults in order for small children to eat (quantity)	**0.26** (0.02)	**0.37** (0.03)	**0.16** (0.02)	***
Most Severe	Borrow food, or rely on help from a friend or relative (quantity)	**0.22** (0.02)	**0.31** (0.02)	**0.13** (0.02)	***
	Have no food of any kind in your household (quantity)	**0.12** (0.01)	**0.17** (0.02)	**0.06** (0.01)	***
	Go to sleep at night hungry because there is not enough food (sufficiency)	**0.13** (0.01)	**0.19** (0.02)	**0.07** (0.01)	***
	Go a whole day and night without eating anything (quantity)	**0.06** (0.01)	**0.09** (0.01)	**0.02** (0.01)	***
Number of observation		**2, 092**	**1, 046**	**1, 046**	

Source: Authors' calculation based on Kwara State UDP Technology Adoption Data, 2015.

***Significant at 1%; Standard errors in parentheses

4.3 USG use on household food consumption coping strategy within treatment villages

Within treatment villages, the use of food consumption coping strategies across households according to USG use is compared. In Table 3, the proportion of households that used any of the strategies at least once a week is lesser among those who used USG compared to non-users. The mean differences in the proportion of households using the less severe strategies are all statistically significantly different between those who used the USG and those who did not. However, the proportion of households that used any of the severe coping strategies does not significantly differ irrespective of USG use. None of the households that used USG employed the strategy of going an entire day and night without eating anything while 3% of non-users of USG adopted such measure to cope with food shortages, though not statistically significant. The t-test statistics of household welfare status, measured as a reduced food consumption coping strategy index (RFCCSI), by USG use shows that households that applied the USG during the farming season recorded a statistically significant lower coping index compared with non-users of the USG; and thus, considered to be more food secure than the non-users. This could be a result of better income/consumption from improved yield associated with USG use.

Table 3: Households' Food Consumption Coping Strategy in Treatment Villages by USG use

Category of Strategy	Food Consumption Coping Strategy Used	Total	USG Status		Sig. of mean difference
			USG use=0	USG use=1	
Less Severe	Rely on less preferred foods	0.77 (0.05)	0.84 (0.05)	0.55 (0.08)	***
	Limit the variety of foods eaten	0.69 (0.05)	0.77 (0.05)	0.41 (0.07)	***
	Limit portion of size at meal-times	0.43 (0.04)	0.49 (0.04)	0.21 (0.05)	***
	Reduce number of meals eaten in a day	0.24 (0.02)	0.26 (0.03)	0.16 (0.04)	*
	Restrict consumption by adults in order for small children to eat	0.15 (0.02)	0.17 (0.03)	0.06 (0.02)	**
Most Severe	Borrow food, or rely on help from a friend or relative	0.13 (0.02)	0.14 (0.03)	0.07 (0.03)	ns
	Have no food of any kind in your household	0.06 (0.02)	0.07 (0.02)	0.02 (0.01)	ns
	Go to sleep at night hungry because there is not enough food	0.07 (0.01)	0.07 (0.02)	0.05 (0.03)	ns
	Go a whole day and night without eating anything	0.02 (0.01)	0.03 (0.01)	0.00 (0.00)	ns
Food consumption coping strategy index (RFCCSI)		2.13 (0.15)	2.40 (0.19)	1.23 (0.22)	***
	Number of observation	1, 046	861	185	

Source: Authors' calculation based on Kwara State UDP Technology Adoption Data, 2015.

*, **, ***, Significant at 10%, 5%, & 1%, respectively; ns = non-significant; Standard errors in parentheses.

4.4 UDP treatment effects on household food security level

We also investigate the effect of UDP technology on household welfare, measured as the household food consumption coping strategy index, using the doubly robust inverse probability weighted regression adjustments (IPWRA) and ordinary least square (OLS). Results are presented in Table 4.

Table 4: Estimated treatment effects of UDP adoption on household food security status

Variable	Estimation method	
	IPWRA	OLS
Average treatment effect on the treated (ATET)	-0.956***	-0.936***
	(0.267)	(0.277)
Head with spouse living together (0/1)	0.629*	0.898
	(0.347)	(0.588)
Head holds leadership position (0/1)	0.068	0.223
	(0.146)	(0.449)
Ln of age of household head (years)	-0.043	0.599
	(0.182)	(0.573)
Ln of education of head (years)	0.057	-0.106
	(0.043)	(0.121)
Ln of household size (AEU)	0.127	-0.756**
	(0.120)	(0.350)
Dependency ratio	0.021	0.284
	(0.059)	(0.176)
Ln of Average farm size (ha)	0.120*	0.088
	(0.070)	(0.197)
Ln of number of plots cultivated	0.299***	-0.375
	(0.098)	(0.339)
Ln of net non-farm income per aeu	-0.019	-0.053
	(0.012)	(0.037)
climate-related effect^{+}	-0.099	0.940*
	(0.159)	(0.556)
Health-related effect^{+}	-0.204*	1.245***
	(0.123)	(0.397)
Market-related effect^{+}	-0.300	2.952***
	(0.199)	(0.764)
Socio-political effect^{+}	-0.239	0.792
	(0.388)	(1.370)
Pests/disease effect^{+}	-0.423**	-0.741
	(0.206)	(0.570)
Constant	-1.908	0.508
	(0.703)	(2.047)
R^2		0.083
Number of observations	1,049	1,049

Source: Authors' calculation based on Kwara State UDP Technology Adoption Data, 2015.

Note: *, **, *** Significant at 10% and 1% respectively; Robust standard errors in parentheses

The estimates from both models provide evidence for a significant causal effect of UDP adoption on household welfare. The IPWRA model estimate (ATET = -0.956, p = 0.000) indicates a significant reduction in the average household food consumption coping strategy index (FCCSI) of UDP technology adopters by 0.956 points compared with non-adopters. This translates to about 44% increase (reduction) in food security (food insecurity) of households who used the urea super granules for rice farming in the production season. In order words, adoption of UDP technology (USG use) has positive implications on household welfare possibly through 1) an increase in food consumption of household own farm production, 2) an increase in farm income resulting from sale of more output due to UDP adoption, and 3) financial savings from reduced production cost particularly those related to fertilizer use and weeding. These improve income earnings could be used by households to smoothen food consumption in the face of food shortages. Therefore, the UDP technology can be regarded as welfare-improving among rural rice farming households.

Table 5: Estimates of treatment effects outcome variables: A summary

Model	coefficient	Robust Std. Err.	P-value
IPWRA			
POmean (Non-USGhhd)	2.356	0.155	0.000
POmean (USGhhd)	1.769	0.373	0.000
ATE (USGhhd vs Non-USGhhd)	-0.588	0.401	0.143
Percentage change in ATE	-0.249	0.165	0.130
ATET (USGhhd vs Non-USGhhd)	**-0.956**	**0.267**	**0.000**
Percentage change in ATET	-0.443	0.106	0.000
OLS	**-0.943**	**0.278**	**0.001**

Source: Authors' calculation based on Kwara State UDP Technology Adoption Data, 2015.
Note: Estimates of average treatment effect (ATE) is statistically not significant.

The treatment model estimates show that households where the heads and their spouses live together are significantly more likely to adopt the UDP technology. This indicates the influence of intra-household joint decisions or second opinion on input use. Both plot size and number of plot owned by farmer estimates are significant and positively correlated with USG use decision. This implies that farmers could allocate a portion of their farms to try new inputs, which could reflect their risk attitudes. Also, these are wealth indicator variables which further show that wealthier households are more likely to adopt the technology compared with asset-poor households. Negative economic situations caused by health, and pest and diseases – related events are more likely to cause farmers not to adopt and use the new fertilizer. The incidence of these risks in the form of sickness and death of household member, and yield loss could cause reductions in farm income and the diversion of available income, both from farm and non-farm sources, away from farm investment.

5. Concluding Remarks

This study presents the adoption effect of urea deep placement (UDP) technology, under a randomized control trial (RCT) methodology, on the food security status rural rice farming households in Kwara state, Nigeria. Results show similar household characteristics across control and treatment household except that the proportion of young male-headed households is more in treatment household compared with control. Similarly, more treatment households cultivate tubers and use improved seeds. The economic effects of climate-related shocks tend to be higher among the control compared with treatment households. Though dietary change and rationing strategies are dominant in the study area, their use is significantly lesser among adopters than non-adopters of UDP technology, and tend to decrease with increasing severity among these households. The treatment effects regression estimates show that households living with their spouses, size and number of plots owned encourage adoption while health, pests and diseases – related events are disincentives. The causal effect estimates indicate that UDP adoption has the potential of decreasing household food consumption coping strategy index and by implication, the household food insecurity level, by 44%. It is therefore evident that urea deep placement technology adoption has a food security implication for rural households and the larger economy of Nigeria.

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