Distributional impact of agricultural technology adoption on rice farmers' expenditure: Case of Nerica in Benin[1]

[1]Didier ALIA and [2]Aliou DIAGNE
[1] Graduate Student, Department of Agricultural Economics, University of Kentucky, d.alia@uky.edu
[2] AfricaRice Center, Cotonou, Benin, a.diagne@cgiar.org
Corresponding authors: Didier ALIA, d.alia@uky.edu
Prepared for presentation at the 59th World Statistics Congress (WSC) of the International Statistical Institute
Hong Kong, China, 25-30 August, 2013

Abstract

In this paper, we examine the link with agricultural technology adoption, inequality and poverty reduction by assessing the distributional impact of NERICA, a high rice yielding variety developed by AfricaRice center, on rice farmer expenditure in BENIN. Using data collected in 2010 within NERICA dissemination project funded by the African Development Bank, we use instrumental base methods to estimate conditional endogenous quantile treatment effect of NERICA adoption on household total expenditure and daily per capita expenditure. The results suggest that NERICA adoption impact, in absolute values, is higher as much as farmers are in high tail of expenditure distribution but no significant evidence for the 90% quantile. However the proportional effect is high in the lower at the lower tail and less important in the middle distribution. These suggest that promoting such technology would not only raise farmer income and then reduce poverty, but will also contribute to income inequality reduction.

Key words : Quantile Treatment Effect, NERICA adoption,

1 Introduction

Rice is the main staple food in many African countries. Its consumption is increasing rapidly because of growing urbanization, storage convenience, ease of preparation and cooking and change in consumers' preferences. Also, rice consumption outpaced production. In fact, the Africa Rice Centre (2007) reported that rice consumption grew by 4.5% between 1961 and 2005 in SSA, while production grew at only 3.18%. In 2010, the self-sufficiency ratio was about 57% indicating that the region relied on the international rice market to satisfy about 33% of its consumption. In 2008, the food crisis and its consequences such as violent urban riots recorded in many countries have revealed that rice is a political and strategic crop and therefore stressed the need for a quick action to increase production and reduce dependency.

The rice sector in Benin, as in other African countries, depends primarily on the effort of poor farmers cultivating on small plots. It is mainly grown in rainfed conditions. The production suffers from many biotic (weeds, insects, etc.) and abiotic stresses (soil fertility, drought, etc.) and socio-economic constraints that limit the productivity and cause high yield losses up to 33% As consequence, increase in rice production is mainly driven by land expansion with slow land productivity.

In Benin, agriculture is a major growth driver and is seen as one of the best strategy to achieving poverty reduction and food security. A study by DFID in 2003 shows that raising agricultural productivity by 1% could reduce the percentage of poor people by between 0.6% and 2% and that no other economic activity generates the same benefit for the poor. To raise rice productivity, much effort has been put on creating high yielding variety (HYV). The adoption of HYV along with best crop management practices and mechanization lead to the Green Revolution in Asia and could achieve the results in Africa (World Bank, 2008).

[1] Acknowledgments: AfricaRice acknowledges the African Development Bank for financial support in the dissemination of Nerica in Africa. The authors thank the National Institute of Agronomic Research of Benin who collects the data. Didier Alia acknowledges the ISI StatsSA fund financial support to attend the 59th WSC and the Department of Agricultural Economics at the University of Kentucky for support in his graduate studies. The authors thanks the AfricaRice Staff, the Chair and graduate students at UK Agricultural Economics department and participants at the 2012 Kentucky Economic Association Annual Conference for useful comments on earlier drafts.

In response to the need of increasing productivity, AfricaRice a CGIA rice research center have developed NERICA varieties in mid 1990s. NERICAS are results of the inter-specific crosses between Oryza sativa, the high yielding rice species from Asia, and Oryza glaberrima, the locally adapted and multiple-stress resistant African rice species is a response to the need to increase rice productivity in Africa They combine the traits of the two parents and has some desirable characteristics such high yield potential, early maturity, resistance to drought, acid soils, insect attack, and good weed competitiveness (Dingkuhn et al., 1999). The potential of NERICA adoption to raise yield has been assessed by several empirical studies in West Africa and points to a heterogeneous impact across and within countries. Diagne et al, (2009) found a positive and significative impact of Nerica on rice yield in Benin of 1.272 t/ha.

Several empirical studies have shown the impact of agricultural technology on various outcomes (income, poverty, expenditure, etc.). These classical econometrics methods fail to deal appropriately with selection bias in observational data collected through household surveys (Imbens and Wooldridge, 2009) because of farmer self-selection problem. This issue may produce bias due to observed difference ("overt bias", Lee, 2005) and/or from unobserved heterogeneity ("hidden bias", Heckman and Vytlacil, 2005). The development of modern approach to program evaluation and the potential outcome framework pioneered by Rubin (1974) and described in Imbens and Wooldridge (2009), enable the estimation of causal effect in a statistically robust manner with a minimal set of assumptions in observational studies.

In assessing the impact of technology adoption, the most commonly interested parameter is mean impact. Frölich and Melly (2010) argue that more than 95 percent of applied econometrics is concerned with mean effects, ignoring distributional effects. They stress that the distribution of the dependent varies across subgroup and examining only the mean effect may results in missing substantial heterogeneity across rice farmers. Distributional effect is also important to correctly target policy and oriented investment decision. Hossain et al. (2003) showed that in Bangladesh, the adoption of HYV of rice had positive effect on the richer households but a negative effect on the poor.

In this paper, we add to previous literature on impact of NERICA adoption, by estimating quantile treatment effect (QTE) of adoption of NERICA varieties on expenditure of rice farmers in Benin. QTE allows the discovering of effect on the entire distribution reducing the susceptibility to outliers. The rest of the paper is organized as follows. Section 2 describes the methodology and section 3 present the background of NERICA dissemination in Benin and some descriptive statistics. The section 4 focuses on the econometric results and discusses the main findings. In last section we conclude and give policy implication.

2 Quantile treatment effect framework

2.1 Overview

Let D stands for a binary treatment variable. Here we are interested in adoption of NERICA, with $D_i = 1$ if the farmer adopted NERICA varieties and $D_i = 0$ if s/he did not adopted. Under the potential outcome framework developed by Rubin (1974), each farmer has ex-ante two potential outcomes: an outcome when adopting a NERICA variety that we denote by Y_i^1 and an outcome when not adopting a NERICA variety that we denote by Y_i^0. Thus the observed outcome Y can be written as follows: $Y_i = D_i Y_i^1 + (1 - D_i) Y_i^0$ (1)

QTE allows for summarizing the distributional impact of a treatment (Frollich and Melly, 2010). In addition to the outcome variable and the treatment status, many other covariates are observed and many other are not. Both the observed and the unobserved could be determinant in identifying and estimating the true causal effect. Four types of QTE are identified in literature, based on condition on the outcome X and the assumption of the selection into the treatment. The following table summarizes the different type of QTE.

Table 1: Different types of QTE

Conditioning to observable	Assumption on treatment	Type of QTE
Explicit Conditioning	Exogenous	Conditional exogenous
Explicit Conditioning	Endogenous	Conditional endogenous
Implicit Conditioning	Exogenous	Unconditional exogenous
Implicit Conditioning	Endogenous	Unconditional endogenous

Source: Authors compilation from various literatures

For each type of QTE, appropriate estimators have been derived in the literature and use in many empirical works. Koenker and Bassett (1978) proposed and estimator for conditional exogenous QTE which has been extended to account for heteroscedascity by Frolich and Melly (2010) quantile treatment effects. Abadie and al. (2002) estimator deal with the endogeineity of the treatment in conditional endogenous QTE. To estimates Unconditional exogenous QTE, the various estimators proposed by Firpo (2007), Frölich (2007) and Melly (2006) can be used. Unconditional endogenous QTE estimator is recently proposed by Frölich and Melly (2008). Detail review of these estimators is provided in Frolich and Melly (2010).

2.2 Estimation

Nerica adoption is self-selected and potentially endogenous. In fact farmer chooses to adopt or not depending on many factors. Also the adoption variable (D) may potentially affect the level of outcome (expenditure). This endogeneity of D raises two types of biases in estimating causal effect: “overt bias” and “hidden bias”. In the case of Nerica Adoption and given the fact that the treatment is not randomly distributed in the population, it is not trivial to assume selection on observable (Diagne and al., 2009). The “hidden bias” will still be persistent leading to wrong causal effect estimation.

To remove both overt bias and hidden bias, we use instrumental variable based methods assuming the existence of a binary instrument. We focus on conditional endogenous QTE and use the estimator proposed by in Abadie and al. (2002) with conditional independence on the instrumental variable and monotonicity (i.e. the non-existence of defiers) assumption. Following Diagne et al (2009), Dontsop Nguezet et al (2011), we use awareness to Nerica as instrument. We assume a linear model for potential outcomes in the form of: $Y_i^d = X_i\beta^\tau + d\delta^\tau + \varepsilon_i$ (2) and $Q_{\varepsilon_i}^\tau = 0$ where δ^τrepresents the conditional QTE at quantile , $Q_{\varepsilon_i}^\tau$ refers to the $\tau - th$ quantile of the unobserved random variable ε_i and β^τ, $\delta^\tau$are unknown parameters. The impact is estimated only for compliers by the weighted quantile regression:

$$(\hat{\beta}_{IV}^\tau, \hat{\delta}_{IV}^\tau) = \text{agrmin}_{\beta,\delta} \sum W_i^{AAI} . \rho_\tau(Y_i - X_i\beta - D_i\delta) \quad (3)$$

With the instrumental quantile weight $W_i^{AAI} = 1 - \frac{D_i(1-Z_i)}{1-P(Z=1|X_i)} - \frac{(1-D_i)Z_i}{1-P(Z=1|X_i)}$ (4)

Because some of the weights are negative while other positive, the optimization problem is not convex. Abadie and al. (2002) suggest an alternative positive weight $W_i^{AAI+} = E(W_i^{AAI}|Y_i, X_i, D_i)$ estimated using non-parametric local linear regression. The instrument model $P(Z = 1|X_i)$ is estimated using local logit regression.

3 NERICA dissemination in Benin and descriptive statistics

3.1 NERICA dissemination in Benin

NERICA varieties have been first introduced in Benin in 1997 through participatory variety selection trial (PVS). The first adoption study conducted in 2004 by Adégbola et al. (2006) estimate adoption rate for the central region to 18% and the potential rate of 50%.which suggests a high potential demand for NERICA sign of an enthusiastic adoption. However, farmers were constrained by inadequate supply of NERICA seed.

In 2005, the African Rice Initiative (ARI), with the support of the African Development Bank has launched a 5-year Multinational dissemination project to support the transfer of NERICA technology from AfricaRice (formerly WARDA) to seven West African countries (Benin, The Gambia, Ghana, Guinea, Mali, Nigeria and Sierra Leone). In Benin the project was implemented in five districts, two in the Colline region (Dassa-Zoumè and Glazoué) and three in Atacora region (Tanguiéta, Matéri and Cobly). A PVS-research is conducted and farmers selected few numbers varieties, among a large number of NERICA varieties, after they experiment it by themselves.

3.2 Data and descriptive statistics

The data used are household survey with an ex-post impact assessment study of Nerica dissemination conducted by AfricaRice and Institut Nationale de Recherche Agricole du Benin in 2010. Multistage stratification sampling methods were adopted to randomly select villages in project region based on participation or not to the project. The total number of village selected is 35. The Non-NERICA villages are chosen within 5 to 10 kilometers radius from the NERICA villages. In each selected village, ten (10) rice farmers were randomly drawn and the total sample size is 350 farmers with 342 farmers really surveyed due to non-response. The survey collects a wide variety of question on household socio-demographic and economic characteristics, the variety known and adopted over time in each village and at farmer level, Farmer contact with various research and/or extension agencies and detail production, income, expenditure variables.

We focus our analysis on estimating the impact of NERICA adoption on farmers' total annual consumption and the consumption per equivalent adult per day. The Table 2 below shows descriptive statistics on the main variable used in this analysis. On average, the household consumption is about 221452 FCA per year with 208.08 FCFA per equivalent adult per day. As shown by the comparison test the consumption among the farmers that are aware of NERICA or that have adopted NERICA varieties is significantly higher than in the consumption of the farmers that are not aware or have not adopted NERICA. Characteristics such as household size, year of schooling, living in PVS village or not, has agricultural training, being member of an association , growing rice in upland are also significantly different across awareness status and adoption status with in most cases higher value for aware or adopting farmers.

Table 2: Descriptive statistics and mean comparison

	Entire sample	Adoption of NERICA		
		Not adopted	Adopted	Diff (tstat)
Number of farmers	342	153	189	
Total expenditure in 2009 (FCFA)	221452.5 (9335.17)	183299.7 (10023.25)	268582.5 (16033.33)	-85282.9 (18224.5***)
Expenditure/ adult in 2009 (FCFA)	208.08 (6.82)	191.2 (8.69)	228.93 (10.62)	-37.73 (13.6***)
Household head age	50.39 (0.7)	50.73 (0.97)	49.96 (1.0)	0.77 (1.4)
Household size	5.8 (0.15)	5.45 (0.2)	6.24 (0.21)	-0.79 (0.3***)
Number of year in the village	45.46 (0.91)	46.16 (1.27)	44.59 (1.3)	1.57 (1.8)
Number of schooling years	2.06 (0.17)	1.68 (0.21)	2.52 (0.28)	-0.85 (0.4**)
Household head Gender	0.77 (0.02)	0.72 (0.03)	0.83 (0.03)	-0.11 (0.05**)
PVS village or not	0.39 (0.03)	0.29 (0.03)	0.5 (0.04)	-0.21 (0.05***)
Has agricultural training	0.53 (0.03)	0.43 (0.04)	0.65 (0.04)	-0.23 (0.05***)
member of association	0.77 (0.02)	0.71 (0.03)	0.84 (0.03)	-0.13 (0.05***)
Growing rice in upland	0.24 (0.02)	0.08 (0.02)	0.44 (0.04)	-0.36 (0.04***)
Growing rice in lowland	0.89 (0.02)	0.91 (0.02)	0.86 (0.03)	0.05 (0.03)

** p<0.1; ** p<0.05; *** p<0.01, standards deviation in bracket ()*

4 Econometric results

We use the instrumental variable based estimator for conditional endogenous quantile treatment effect proposed by Abadie and al. (2002) to assess the distributional impact of NERICA adoption on expenditure in Benin. We use local logit regression to estimate the propensity score and local linear regression for the estimation of the positive weights and the variance. Results for the household total expenditure are displayed in Table 3 and the results for the household expenditure per adult equivalent are showed in table 4. We report the results for the conditioning variables for completeness but dot not discuss them to keep the focus of the paper on the adoption impact. We also graph the estimated conditional QTE and the corresponding confidence interval to have a clear picture of the NERICA adoption impact in each quantile.

The results (Figure 1 appendix) show that in absolute value, NERICA adoption impact is high as much as the farmer is in a high quantile with no significant evidence for farmers in the 90%-percentile. However the proportional impact shows a different pattern. In fact, NERICA adoption had a higher proportional impact on the lower tail of the expenditure distribution and the upper tail than the middle. This seems like a desirable distributional outcome most especially for the lower tail. The comparison of the QTE results with the corresponding simple OLS regression (column OLS in the econometric results table) shows clearly quantile effect show more information in terms of heterogeneity of the impact than the simple average impact.

The total expenditure increase due to NERICA adoption is about 30296 FCFA for farmers and grows slowly under the median. This gain grows more rapidly from the median value to reach 66364 FCFA for 80%-percentile. The impact on the daily expenditure per capita decreases slightly under the median from 35 FCFA/capita/day for the 10%-percentile to 27 FCFA/capita/day for the 40%-percentile before rising for farmer above the median to reach 61 FCFA/capita/day for the 85% percentile.

5 Conclusion

This paper uses the instrumental variable base estimator of quantile treatment effect proposed by Abadie and al. (2002) to assess the distributional impact of NERICA adoption on farm household total expenditure and on the daily per capita expenditure. We use awareness to NERICA as an instrument and find out that the quantile treatment effect reveals more information on the heterogeneous impact than the simple average treatment effect. Our results confirm the effect of NERICA adoption in raising expenditure and then to alleviate poverty. However, this effect is not the same across the distribution on expenditure. In absolute value the impact is high for farmer in the upper half distribution tail. Nonetheless, the proportional impact reveals that the impact is much high for poor farmer and farmer with some high expenditure but seems to be less important for farmer in the middle of distribution.

In terms of policy implication, our findings suggest that NERICA has the potential to alleviate poverty and much effort need to be done to widely disseminate this rice cultivar which performs well in African rainfed environment. Also, we suggest that continuous effort may be put in targeting poor farmer in NERICA dissemination as their expenditure gain is relatively high. But there is also a need to not totally discriminate farmer access to NERICA seed with respect to poverty status. As we shows, rich farmers earn more money from NERICA adoption as they may have easy access to fertilizer and complementary technology that guarantee to NERICA to reach it high yield potential.

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7 Appendix

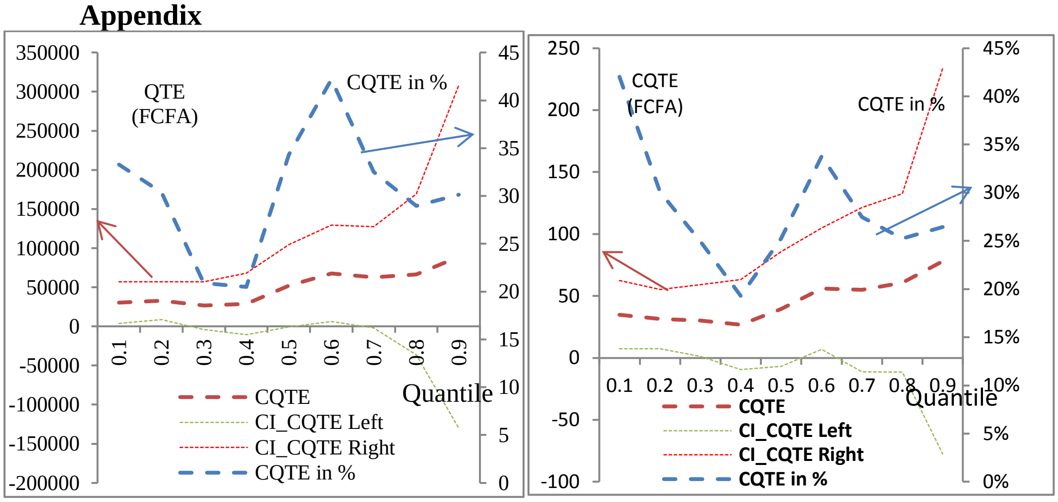

Figure 1: Conditional QTE of NERICA adoption on household expenditure (left) and daily per capita expenditure (right)