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Exploring the potential for green revolution: a choice experiment on maize farmers in Northern Ghana

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Abstract

Conventional modelling approaches to understand farmers' adoption preferences tend to ignore the range of choices farmers face, as well as the trade-offs among various possibilities to improve crop yield. To address this deficiency, this study employs the choice modelling approach to examine famers' valuation of various attributes under a Green Revolution package to improve crop yield. It was found that the use of chemical fertilisers and drought-resistant seed varieties was highly valued by farmers in the two regions of Northern Ghana. Information on farmers' willingness to pay for chemical fertilisers is a useful tool for reducing the current high fertiliser subsidy. Food-insecure farmers, on the other hand, valued organic fertilisers and drought-resistant seeds, while female-headed households among food-secure farmers had a preference for organic fertiliser. Legume intercropping to fix soil fertility has some potential for promotion among farmers, but it was less valued than chemical fertilisers. Farm households did not appear to be interested in using seed varieties that vary in time to maturation, which have potential benefits in the face of current climate variability and future climate change. More in-depth study is required to better understand these issues.

Key words: choice experiment; green revolution; food insecurity; random parameter model; Ghana

1. Introduction

The 2008/2009 global food price hike placed food security at the top of the policy agenda for many developing countries. In particular, the combination of this price increase and low agricultural productivity in Africa has put this issue at centre stage in many African countries (see Abbott & Battisti 2011). In turn, the concern surrounding food security has once again brought to the forefront discussions on the need and potential for a Green Revolution in sub-Saharan Africa (SSA), of the type that was successfully experienced in Asia (Otsuka & Kalirajan 2006; Hunt & Lipton 2011; Otsuka & Kajima 2011). Some specialists, however, have voiced doubts about the possibility of a green revolution in SSA (World Bank 2007; Voortman 2013). Nevertheless, the efforts towards finding a solution to this problem has seen commitment and global participation with the setting up in 2006 of the Alliance for a Green Revolution in Africa by the Bill and Melinda Gates Foundation, and the African Green Revolution Forum, which was founded in 2010.

Given the widespread interest in this area, this paper's first contribution is the examination of the potential for a green revolution in Ghana. The importance of such a revolution in Ghana should not be underestimated, because if successful, it may address the gap of 6 000 kg/ha (or 6 metric tons/ha) between current maize yield and what is achievable on farm (CIMMYT 2013).[1] The second contribution is that the analysis from a micro-economic perspective is based on a choice experiment (CE). This is done using a survey of Ghana's maize farmers' preferences for adopting various features of the green revolution in their farming practices. The third contribution lies in the comparison of farmers' preferences for adopting farm practices in food-secure and food-insecure households. The direct focus on food security and farm management practices to improve agricultural performance is a new dimension, which has not been considered before. The analysis uses Ghana as a case study for the following reasons. First, using a dynamic computable general equilibrium model, Breisinger *et al*. (2009) identified the impact of a green revolution in Ghana to be strongly pro-poor so as to lower the national poverty rate to 12.5% by 2015; coupled with livestock productivity growth, the green revolution enables an annual agricultural output growth of 6% over the next 10 years. Second, relative to other African countries, Ghana has performed well, with an annual agricultural growth of 5.5% over the decade of 2000; but, as noted by the Ministry of Food and Agriculture [MOFA] (2010), this is unsustainable given that it was driven largely by land expansion. Lastly, the north-south poverty divide in Ghana has worsened over time, with 63% of the population in the north being poor compared to 20% in the south, and this has contributed in part to Northern Ghana having 26% of its population being food insecure (World Food Program [WFP] 2012).

Given the disparity within Ghana, it is important to understand farmers' decision-making processes in Northern Ghana towards good farm practices in order to raise agricultural yield for sustainable growth in the country. Within Northern Ghana, the northern region and upper east region (which is the poorer of the two regions) were chosen for a comparative analysis of maize farmers. Maize is one of the most important cereal crops in Ghana, being a major staple food for most communities and contributing about 20% of calories to their diet (Braimoh & Vlek 2006). The rest of the paper is organised as follows. The next section details the choice of experiment design and data collection. Section 3 describes the empirical model and variables used for analysis. The results are discussed in section 4, and the last section concludes.

2. Choice experiment (CE)

2.1 The choice experiment approach

The CE approach draws upon Lancaster's economic theory of value (Lancaster 1966), which posits that individuals derive utility from the underlying attributes of the product that is being valued. This approach assumes that individuals' preferences (as captured by some notional utility function) are revealed through their choices. Early empirical applications of CE were in the disciplines of marketing and health (see Green & Srinivasan 1978; Propper 1990) before its extension to the environment (Adamowicz *et al*. 1994; Hanley *et al*. 1998; Blamey *et al*. 2000), tourism, cultural heritage, noise pollution, forests and water resources and food labelling (see Crouch & Louviere 2004; Birol & Koundouri 2008). In the evaluation of farm behaviour, studies using CE on agricultural crops include Baidu-Forson *et al*. (1997), Qaim and De Janvry (2003), Ndjeunga and Nelson (2005), Birol *et al*. (2009), Asrat *et al*. (2010), Yorobe *et al*. (2010) and Blazy *et al*. (2011).

The main advantage of CE is that it allows for the analysis of preferences for complex multi-attribute goods when limited market data are available. In the context of farming practices, farmers' preferences are governed by their budget constraints, expectations of input and output prices, their traditional farm management practices and knowledge of technology adoption. A CE enables us to capture farmers' preferences by asking them to choose from various options that entail trade-offs between the options. Understanding the choices farmers make based on such information will

[1] It is also possible that massive increases in production could lead to a drop in price.

improve the design of appropriate policy interventions. Although the technologies currently are available in Ghana, the possible scenarios (e.g. specific government packages) to promote them do not exist. Therefore, the CE is a useful tool to analyse such future (or hypothetical) scenarios.

2.2 Choice experiment design and survey

The particular aspects of the green revolution[2] for maize cultivation considered in this paper are the use of i) improved varieties resistant to disease and drought; ii) various methods to improve soil fertility; and iii) varieties maturing at different times. These were identified in focus group discussions with farmers and agricultural officials from the Ministry of Food and Agriculture in June 2013. These features of the green revolution (also broadly in line with Hunt and Lipton 2011) form the attributes of a farming practice package that farmers would consider practically. Each attribute is varied across plausible levels encompassing the range of options that farmers would consider in their effort to improve their maize yields. The reasons for the chosen attributes and their levels as set out in Table 1 are explained further below.

Table 1: Attributes and levels of the choice experiment

Attributes	Levels	
Maize maturing varieties	**Late maturing**	(101–120 days)
	Middle maturing	(90–100 days)
	Early maturing	(76–89 days)
Resistance of maize variety	**Disease-resistant improved variety**	
	Drought-resistant improved variety	
Improved soil fertility	**No fertiliser**	
	Intercrop with legumes	
	Organic fertiliser (manure)	
	Chemical fertiliser	
Price of combined package for an acre of land	GHC* 100 (US$ 43.10)	
	GHC 250 (US$ 107.65)	
	GHC 400 (US$ 172.25)	
	GHC 550 (US$ 236.85)	

Notes: The particular level within each attribute in bold is used as the base in the estimations
* GHC = Ghanaian cedi
1 acre = 2.47 ha
The exchange rate of US$1 to GHC 2.32 (21 December 2013) was used

First, three types of maize varieties with different days to maturing were considered. This attribute enables crop diversification, since the particular maize variant chosen will determine whether farmers could plant other crops before planting maize or after harvesting maize. In addition, farm households may want to plant early-maturing maize varieties for personal consumption and stagger the cultivation and harvesting of maize crops for sale if necessary. For instance, green maize is maize harvested intentionally before it reaches its full term, to be boiled and consumed or sold immediately. Grain maize, on the other hand, is stored and sold to be ground into maize flour as a staple crop. Cultivation in phases also enables harvesting at different times. The second attribute considered was the choice between the disease-resistant maize variety and the drought-resistant variety; drought and various foliar diseases are among the major causes of the low yield of maize in Ghana (CIMMYT 2013).

The third attribute was improving soil fertility. Unlike the case in Southern Ghana, Northern Ghana's soil fertility and organic soil matter are poor, with runoff also being high because of the concentration of rains in short periods (Diao & Sarpong 2007; World Bank 2011). Voortman (2013)

[2] Nobel Prize Laureate Norman Borlaug (also known as the father of the green revolution), in his Nobel lecture on 11 December 1970, referred to improved seeds as the 'catalysts' that ignited the green revolution and mineral fertilisers as the 'fuel' that powers it.

highlights that poor soil properties are a crucial reason for the failure of the green revolution in Africa, and it thus is necessary to improve soil fertility in order to improve maize yield. A number of options of doing that are provided for farmers to choose from (see the levels under this attribute in Table 1). These include the use of inorganic/chemical fertiliser, the use of manure (organic fertiliser), as well as intercropping maize with legumes such as cowpea, groundnut and soybean. Intercropping is said to fix the nitrogen content of the soil and enhance organic soil matter, but requires some knowledge from farmers with regard to the spacing of crops and the use of more labour (Wiredu *et al*. 2010). Manure, on the other hand, is cheaper compared to chemical fertiliser and is heavily used in Northern Ghana (Wiredu *et al*. 2010). Without government subsidy,[3] chemical fertilisers are very expensive, being priced at between US$40 and US$50 per 50 kg bag. The recommendation for maize in Northern Ghana is to use 60 kg/hectare (Alliance for a Green Revolution in Africa [AGRA] 2012), but the average chemical fertiliser use for crops in Ghana is only about 20 kg/hectare (AGRA 2013). Although chemical fertiliser use has been shown to improve yield in general, Marenya and Barrett (2009) show that low soil organic matter commonly limits the yield response to fertiliser application, and thus the soil science community must advise how best to reap significant benefits from fertiliser application.

Lastly, in order to obtain the marginal worth of each of the levels of the attributes in Table 1, a price (or cost) was included as part of the option presented to farmers. To obtain the price of the combined package to improve maize yield, a convenience sampling was undertaken of 30 farmers chosen to be representative of the types of farmers who eventually would be surveyed. Bearing in mind the need to minimise hypothetical bias,[4] the convenience sample of farmers was first reminded to think of their budget constraints and informed that government assistance programmes could not be properly designed without a realistic measure of their true willingness to pay (WTP); they then were asked to state the maximum and minimum price per acre of cultivated land that they would be willing to pay for a combined package of green revolution best farming practices to raise maize output. To err on the conservative side, the range of minimum WTP amounts stated were used to generate four plausible prices to be considered for the specific packages in the final survey.

After the attributes and their levels were confirmed, an experimental design was developed to determine the combination of attribute levels in each alternative bundle. A full factorial experimental design allowed us to estimate not just the main effect of each attribute, but also the effect of interactions between all the attributes. However, the various attributes and their respective levels would have provided a total of $3 \times 2 \times 4 \times 4 = 96$ alternatives, which would be difficult and expensive to implement in a survey. Since the main aim of the study was to explicate the main effect of each attribute and, at most, interactions between two variables, a fractional factorial design would suffice. The design adopted is the Street-Burgess design, a D-efficient design[5] (Street *et al*. 2005) in which individuals are presented with alternatives that are maximally different. In other words, the experiment produces corresponding options with attribute levels that always will be maximally different. In total, 16 blocks of four choice sets were generated, and each farmer was shown a choice set with four choice cards.[6]

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[3] The level of fertiliser subsidy accounts for a large part of the budget of Ghana's Ministry of Food and Agriculture, and this is unsustainable and threatens the very existence of the programme (International Food Policy Research Institute [IFPRI] 2012).

[4] Hypothetical bias is defined as the difference between the stated willingness to pay (WTP) and a valid measure of actual WTP.

[5] Empirical implementation of the Street-Burgess design in marketing, transportation and applied economics suggests that the methodology can provide optimal or nearly optimal designs for estimating the parameters of multinomial logit models and deliver superior efficiency, in practice as well as in theory (Street *et al*. 2005).

[6] The pilot test of the survey showed that farmers coped well with four choice cards in each choice set.

Table 2: Example of a choice card

		Option A	Option B	Option C Choose neither
	Maturity	Early maturing	Late maturing	Neither A nor B I <u>do not want</u> to pay for any package to improve my maize yield
	Resistance	Disease-resistant	Drought-resistant	
	Fertiliser	Organic fertiliser	Legume intercropping	
	Price of package	GHC 550	GHC 100	

Table 2 shows an example of a choice card with two alternatives and the status quo as another alternative. The status quo alternative (of doing nothing different) is provided to minimise bias in the WTP estimates, mitigate yea-saying bias (Bateman *et al*. 2002) and enhance the reality of the choice situation, as respondents may exercise their right to do nothing if the alternatives presented to them are perceived not to improve their current level of utility (Ryan *et al*. 2008). Opting for the status quo means that the farmers will stick to their current farming practice. The scenario described to the farmers at the start of the choice experiment is shown in Appendix 1.

3. Empirical model

The CE approach has an econometric basis in models of random utility (McFadden 1974). The basic model assumes that the farmer's utility depends on choices made from a choice set *C*, and the utility function has the following form:

$$U_{ij} = V_{ij}\,(Z_{ij}, S_i) + e_{ij} \qquad (1)$$

where, for any farmer i, a given level of utility will be associated with any alternative choice of attributes j to improve farm yield. Utility derived from any of the alternatives depends on the attributes (Z) of the package and the social and economic characteristics (S) of the farmer. Assuming that the relationship between utility and characteristics is linear in the parameters and variables function, and that the error terms are identically and independently distributed[7] in accordance with the extreme value Gumbel distribution, the probability of any particular alternative j being chosen can be expressed in terms of a logistic distribution, with the basic model expressed as

[7] This characteristic of the error terms has an equivalent behavioural association with a property known as the independence of irrelevant alternatives. This property states that the ratio of the choice probabilities of any pair of alternatives is independent of the presence or absence of any other alternatives in a choice set. In other words, all pairs of alternatives are equally similar or dissimilar (Hensher *et al*. 2005).

$$P_{ij} = \frac{e^{\lambda V_{ij}}}{\sum_{h \in C} e^{\lambda V_{ih}}} \quad (2)$$

where λ is a scale parameter that is inversely proportional to the variance of the error terms and commonly normalised to one for any one dataset (Ben-Akiva & Lerman 1985). To estimate equation (3), a linear-in-parameters utility function (also known as the indirect utility function) for the j^{th} alternative takes the form:

$$V_{ij} = ASC + \beta_1 Z_1 + \beta_2 Z_2 + \ldots + \beta_n Z_n + \delta_1 (S_1 *ASC) + \delta_2 (S_2 *ASC) + \ldots + \delta_m (S_m *ASC) \quad (3)$$

where ASC is the alternative specific constant that captures the average effect of the utility of the factors not associated with a specific attribute that have not been included in the model. The number of attributes is n and the number of social and economic characteristics of the farm family used to explain the choice is m. The vectors of coefficients β_1 to β_n are attached to the vector of attributes, while δ_1 to δ_m are the vector of interaction terms that influence utility.

Before deciding on the estimation technique for the above model, we tested the validity of the assumption of independence of irrelevant alternatives (IIA), using the Hausman and McFadden (1984) test. This assumption was rejected and therefore we used the mixed logit or random parameters logit model, which does not assume IIA.

4. Empirical results

Before discussing the empirical results, some summary statistics of key variables in Table 3 provide information on the two regions.[8] It can be seen that there is no statistically significant difference in the average age of the farm household head in the two regions. However, household heads in the Northern region tend to be better educated than in the Upper East region. The average experience of the household head in maize farming and average land cultivated are about two times more in the Northern region than in the Upper East region. In the Upper East, household size and the proportion of farmers with farm debt are much lower, due perhaps to the smaller land size of farms in the area. The local maize variety is predominantly preferred over the modern varieties in the Upper East region. In relation to food insecurity,[9] the sample data collected is in contrast to that of the WFP (2012), which indicated that the proportion of food-insecure households in the Upper East region (where 28% of households are either severely or moderately food insecure) surpassed that in the Northern region (10% of households). Such a difference may be because ours is a perceived measure by the respondents, while the WFP used a set of criteria for its assessment.

[8] The socioeconomic characteristics of the sample are similar to those in the 2010 census for the study area (Ghana Statistical Service [GSS] 2012). The average age of the farm household head was 46.2 years; 83.6% of farm households were male headed; the average household size was 8.1; and the average cultivated land area was 1.45 ha.

[9] Food insecurity is measured by an ordered variable of ‘food shortage most times’ and ‘food shortage sometimes’, and ‘no food shortage’.

Table 3: Summary statistics of key variables

Sample size (number of farmers)	**Northern region** $n_1 = 270$	**Upper East region** $n_2 = 130$	***p*-values, test of equality of the means/proportions**
	Mean (standard deviation)		
Age of household head (years)	45.72 (12.24)	45.32 (15.38)	0.78
Education of household head (years)	5.47 (1.83)	4.34 (1.11)	0.00
Experience of household head in growing maize (years)	21.02 (13.43)	10.70 (7.34)	0.00
Cultivated land size (acres)	6.79 (4.77)	3.04 (1.68)	0.00
Household size	15.17 (9.00)	8.53 (5.02)	0.00
Distance to nearest agricultural extension office (km)	9.51 (7.81)	7.64 (2.93)	0.00
	Percentage of farmers		
Food-insecure households[1]	36.54	20.24	0.00
Female-headed household farmers	15.68	19.70	0.31
Marital status of household head			
Married	96.79	70.45	0.00
Divorced/separated/widowed	1.74	13.64	0.00
Single	1.48	15.91	0.00
Household has farm debt	13.48	2.31	0.00
Household head has secondary occupation	27.68	28.03	0.98
Use of more local seed varieties over improved varieties	52.13	81.05	0.00
Extent of	Likert scale* (4-point)		
Intercropping maize with legumes	1.5	3.1	
Use of organic fertiliser	1.4	3.9	
Use of chemical fertiliser	3.3	3.0	
Use of early-maturing variety	1.4	1.7	
Use of middle-maturing variety	2.6	2.3	
Use of late-maturing variety	2.2	1.8	

Note: [1] Households that reported food shortage most times and some times
* 1 represents 'not at all', with an increasing order towards a very positive statement

Table 4 shows the random parameter model estimates for the sample farm households in the Northern and Upper East regions of Ghana. The ASC is positive and significant, which means that farmers prefer alternative choices to improve farm yield compared to their current practices. The negative and significant price coefficient implies that a higher price for the package of options would decrease the farmers' utility, as expected. By and large, the estimated coefficients on the attributes are significant and their standard deviations reveal significant unobserved heterogeneity across individual choices for all attributes. In order to obtain information about the sources of individual heterogeneity, socio-economic variables were allowed to interact with the ASC and the choice attributes.

Table 4: Random parameter model estimates for regions of northern Ghana

	Northern region		Upper East region	
	Coefficient	Standard error	Coefficient	Standard error
Non-random parameters				
ASC	5.6154**	1.4572	3.2613**	1.3789
Price	-0.009**	0.0020	-0.0013**	-0.0003
Land size * ASC	0.2697*	0.1786	0.6211**	0.2927
Farm debt * ASC	-1.2805*	0.6911	0.7481	05812
Secondary occupation *ASC	0.7521	0.6939	1.2386**	0.5631
Food security * ASC	0.1961**	0.0362	0.4332**	0.1891
Random parameter means				
Early maturing	-0.1564	0.1086	0.5341	0.3735
Middle maturing	0.3157	0.1776	0.4461*	0.2655
Drought resistant	0.4203**	0.2123	0.0541**	0.0271
Organic fertiliser	-0.1693	0.1376	0.0176	0.0113
Chemical fertiliser	0.5395**	0.2569	0.0644*	0.0372
Legume intercropping	0.1745**	0.0877	0.0316**	0.0159
Random parameter standard deviations				
Early maturing	0.1312*	0.0785	0.4285*	0.2279
Middle maturing	0.1221*	0.0735	0.2891*	0.1710
Drought resistant	0.0423**	0.0211	0.0541**	0.0291
Organic fertiliser	0.2349*	0.1389	0.1364*	0.0766
Chemical fertiliser	0.0889**	0.0447	0.0519**	0.0235
Legume intercropping	0.0195*	0.0256	0.0376*	0.0189
Heterogeneity in mean of random parameters				
Chemical fertiliser * farm debt	-0.2231**	0.0456	-0.4981**	0.2026
Chemical fertiliser * land size	0.2013**	0.1645	0.3822**	0.1956
Legume intercropping * land size	0.1167**	0.0442	0.0975**	0.0582
Legume intercropping * farm debt	-0.0682**	0.0312	-0.0875**	0.0442
Model statistics				
Number of observations	1080		520	
Log likelihood	-743.63		-354.13	
Pseudo R^2	0.354		0.390	

Note: ***, ** and * indicate 1%, 5% and 10% significance levels respectively

Some socio-economic factors, such as age, experience in maize farming, distance to agricultural extension office and gender[10] of household head, were found not to influence the use of alternatives for yield increase and thus were not included in the final model. But having farm debt in the Northern region was a deterrent to choosing alternatives, while farmers with secondary employment in the Upper East were more likely to try alternatives. Having a second job would indicate extra income for farmers in the Upper East to invest in their land, and this is confirmed by the relatively lower percentage of farmers with debt in this region, as seen in Table 3. In the Northern region, the prevalence of farm debt may be attributed to larger families (as seen in Table 3), and this may render them more inclined to choose the status quo (tried-and-true methods) rather than experiment with new alternatives for which they have to pay.

On the other hand, in both regions, farmers with bigger plots of land were likely to consider alternatives. This partially reflects the current farming practice in the extent of legume intercropping, as seen in Table 3. Also, in both regions, farmers with bigger farms, in particular, preferred to take on legume cropping, as well as to use more chemical fertiliser. If land size is indicative of richer (or more enterprising) farmers, this finding is understandable, since these are farmers who are willing and able to pay for various ways to improve their yield. In addition, those with farm debt did not make any of these choices.

[10] This is broadly in line with Doss and Morris (2000), who show that there is no significant association between the gender of the farmer and the probability of adopting modern varieties and/or fertiliser in Ghana.

It can be seen that farmers in both regions preferred drought-resistant varieties to disease-resistant varieties in order to improve yield. In fact, the use of a heat-tolerant maize variety has been shown to produce substantial gains in maize yield – of about 30% – in Northern Ghana (see Tachie-Obeng *et al*. 2013). The preference for drought-resistant seeds also reflects concern about the lack of rainfall, given that agricultural production in these regions is mostly rain-fed. In terms of time of maturing of the maize variety, the use of middle-maturing varieties (compared to late-maturing variety) in both regions influenced farmers to choose alternative options to increase farm yield, but only at the 10% level of significance. This indicates limited responsiveness towards the middle-maturing variety. One reason could be that the farmers were already using this variety the most, as seen in Table 3, and this is consistent with Ragasa *et al*. (2013), who found that the middle-maturing *Obatanpa* maize variety was the most popular improved variety. Also, the prices of early-, middle- and late-maturing improved varieties in Ghana are very similar, and thus the choice of maize variety by maturity is not a major influence on farmers' decisions when it came to choosing alternative options.

Preferences for improving soil fertility showed that farmers in both regions were indifferent about either organic fertiliser and no fertiliser use. While this can explain the low use of organic fertiliser in the Northern region (see Table 3), it contrasts with the high use of organic fertiliser in the Upper East. It is possible that the relatively poor Upper East region cannot afford chemical fertiliser, while in the Northern region there could be more competing demands on the use of organic fertiliser, such as acquiring livestock feed, but this needs to be investigated further, as it was beyond the scope of this study. Also, in the Upper East, the average farm size is half that in the Northern region, and intercropping with legumes (which are nitrogen-fixing) is much more prevalent and hence not much fertiliser may be perceived to be needed. However, there was a preference for chemical fertiliser in both regions, albeit at the 10% significance level in the Upper East, although at a 5% significance level in the Northern region. These results are compatible with the previous explanation. Also, the survey results showed that 81% of the farmers in the Upper East used more local varieties than improved varieties compared to 50% of the farmers in the Northern region. Not only do local maize varieties require less fertiliser than improved varieties,[11] but they are cheaper than improved varieties, as they are obtained or bought from other farmers. Improved varieties, on the other hand, often are purchased from the market.

Lastly, the food security variable was significant for both regions, indicating that the more food secure the household, the more likely it was to opt for alternatives A or B. To examine the extent to which preferences for the specific attributes were influenced by the status of food security, the sample was stratified into two groups, namely 'food secure' and 'food insecure'. As there were not enough observations for each of these groups in each region, the sample from both regions was combined to reflect the two food security situations. Once again, the random parameter model (see Table 5) provided a better fit than the conditional logit model.[12] It can be seen that the standard deviations of the random parameters were all significant, including the price, but when the varieties maturing at different times were randomised, the model could not converge. Thus they were considered as non-random in the model. The ASC was positive and significant, once again, indicating that farmers preferred the options over the 'no-action' scenario. The early-maturing variety had no impact and the middle-maturing variety had a statistically weak positive influence on the famers' choice of options. Various socioeconomic factors, when included, were not significant and hence were dropped from the model. As expected, price had a negative and significant influence and drought-resistant seeds were preferred regardless of the food security status of the

[11] Personal communication with crop scientists at the Savannah Agriculture Research Institute in Tamale in the Northern region of Ghana.
[12] The log likelihood ratio test did not accept the null hypothesis that the random parameter model and the conditional logit model estimates are equal.

farmers. However, organic fertiliser was the only other attribute that affected food-insecure farmers' preferences positively, while legume intercropping and chemical fertiliser were preferred by food-secure farmers. With regard to the source of heterogeneity, only the female-headed households among the food-secure farmers had a preference for the use of organic fertiliser and, overall, the female-headed household farmers were not keen on paying more for the various options to improve farm yield.[13] The latter could reflect the fact that women have less access to credit, but this needs to be examined in line with the effectiveness of microfinance institutions in the region.

Table 5 Random parameter model estimates based on farmers' food security (pooled data from the two regions of Northern and Upper East Ghana)

	Food secure		Food insecure	
	Coefficient	Standard error	Coefficient	Standard error
Non-random parameters				
ASC	4.6926**	2.6034	5.2284**	2.3007
Early maturing	0.2417	0.1611	0.1163	0.0761
Middle maturing	0.1683*	0.0991	0.1072*	0.0915
Random parameter means				
Price	-0.0012**	0.0061	-0.0024**	0.0012
Drought resistant	0.0428**	0.0215	0.0564**	0.0285
Organic fertiliser	0.2165	0.1388	0.0348**	0.0175
Chemical fertiliser	0.0837**	0.0421	0.1075	0.0768
Legume intercropping	0.0347**	0.0158	0.1147	0.0760
Random parameter standard deviations				
Price	0.0003**	0.0014	0.0014**	0.0006
Drought resistant	0.0367**	0.0186	0.0206**	0.0101
Organic fertiliser	0.0412**	0.0209	0.1255**	0.0597
Chemical fertiliser	0.0185**	0.0092	0.1773**	0.0896
Legume intercropping	0.1284**	0.0635	0.0571**	0.0271
Heterogeneity in mean of random parameters				
Price * female household head	-0.2231**	0.0456	-0.4981	0.2026**
Org fert * female household head	0.2013	0.1645	0.3822	0.2731
Model statistics				
Number of observations	1 175		425	
Log likelihood	-993.47		-618.92	
Pseudo R^2	0.263		0.219	

Note: ***,** and * indicate 1%, 5% and 10% significance levels respectively

Based on the estimates obtained in Tables 4 and 5, the marginal value, also known as the marginal willingness to pay (MWTP), or implicit price of a unit change in a single attribute level was calculated using parametric bootstrapping with 10 000 replications, following Krinsky and Robb (1986). The farmers' MWTP for only the levels of the attributes that were significant were computed for an acre of land, as shown in Table 6. From a policy standpoint, the information on which attribute levels are valued more is useful to understand farmers' relative preference to pay for these attributes.

[13] Most other socioeconomic factors, when allowed to interact with the attributes, provided similar results for the food-secure groups to those found in Table 4, but were insignificant for the food-insecure groups. These results were not reported to conserve space, but are available upon request.

Table 6: Farmers' marginal willingness to pay for various attributes (US$/acre)

	Northern region	Upper East region	Food secure	Food insecure
Drought-resistant variety	20.13	17.92	15.37	10.13
Chemical fertiliser	25.84	21.36	30.06	-
Organic fertiliser	-	-	-	6.26
Legume intercropping	8.36	10.46	12.48	-

Note: A dash means that the coefficient on that attribute level was not significantly different from zero in Tables 4 and 5, and so marginal willingness to pay was not computed for that attribute level.

It can be seen that chemical fertiliser was valued most highly and that farmers were willing to pay for it, thus indicating that there is some leeway to reduce the current high subsidy for fertilisers provided by the government. With these subsidies, fertiliser prices are reduced to a third of their original price in Ghana,[14] and several studies, as noted by Denning *et al*. (2009), have argued for and against the use of input subsidies. Table 6 also shows that drought-resistant seeds are more valued than legume intercropping by all groups. Farmers in the Northern region are willing to pay more than the Upper East farmers for the drought-resistant seeds and chemical fertiliser, but they are willing to pay less than their counterparts to undertake legume intercropping to fix soil fertility. The food-insecure farmers, on the other hand, are willing to pay for the use of organic fertiliser, as it is a far cheaper option than paying for chemical fertiliser.

5. Conclusion

Conventional modelling approaches to understand farmers' adoption preferences ignore the range of choices farmers face and the trade-offs among various possibilities to improve crop yield. The choice modelling approach in this study overcomes this drawback by considering farmers' valuations of various attributes underlying the green revolution to increase farm yield. Evidence shows that farmers certainly want to adopt these packages for sustainable production, and that they view the drought-resistant seed variety as important. Thus efforts needs to be made in relation to the distribution of these seeds to ensure their availability to farmers. The relative importance of the different ways of increasing yield, however, depends on the regions, the farmers' food security status, and some socioeconomic characteristics.

Farmers' willingness to pay for chemical fertilisers is an important guide to how the current high fertiliser subsidy can be reduced. However, there was no interest in the potential gains from the use of the seed varieties with varying times of maturity. The high use of local varieties over improved varieties still prevails, and thus this study did not look at the use of hybrid seeds or certified seeds, as these have been reported to be sorely lacking in Ghana (see MOFA 2010; Ragasa *et al*. 2013). Instead, other aspects of the green revolution were examined to shed light on the potential for promoting them among farmers, based on the farmers' chosen preferences to improve yield.

Among food-secure farmers there were differences in the preference for organic fertiliser and willingness to pay among the female-headed households. The food-insecure farmers, on the other hand, were most satisfied with the use of drought-resistant seeds, followed by the benefits of using organic fertiliser. While the possibility of the green revolution package of options working for food-insecure farmers is looking rather weak, more in-depth study is needed to better understand the preferences and attitudes of this group of farmers so that it will be possible to help them. This may include information on the quality of their land, land slope, access to borrowing, farm organisation membership and the extent of their social networks, which may influence food-insecure farmers' preferences and ability to pay to improve farm yield. Finally, it would be useful to consider issues such as market access and prices received.

[14] Personal communication with agricultural officers at the Ministry of Agriculture in Accra, Ghana.

To conclude, it is worthwhile to briefly consider some limitations of the study. As the stated preference approach, the choice experiment is subject to hypothetical bias. Although efforts (e.g. reminding respondents about their budget constraints) were made to minimise such bias, the fact remains that how much people are actually willing to pay in reality may not be the same as what they report in a survey situation. The study could have collected data on agro-ecological and spatial variables such as rainfall, temperature, precipitation, distance to market, etc. These variables are likely to affect the farmers' choice of, say, drought- versus disease-resistant varieties. Finally, in this study we employed best practices as recommended by Bennett and Birol (2010).[15] However, it should be borne in mind that, in general, farmers in developing countries tend to lack survey experience and they may not trust the anonymity of their responses. Therefore they may not reveal their true preferences.

In terms of future research, two strands are worth exploring. While the aim of the green revolution is to increase farm yields, this needs to be addressed together with ways of adapting to climate change, which is a rising concern – particularly for African countries. In addition, the long-term goal of the green revolution goes beyond raising agricultural productivity (which is what this study focused on) to raising farm incomes. The latter depends on what happens from after the harvest up to the point of sale. Thus it is important to examine the post-harvest side of crops in future work. Data shows that up to 35% of maize is lost along the chain, and this major post-harvest loss is a potential cause of food insecurity (MOFA 2010). Factors associated with such losses include limited knowledge of post-harvest handling, poor harvesting methods, poor storage systems, poor access to information on markets, and poor transportation methods and equipment.

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[15] These include using focus groups prior to the development of the survey instrument; pre-testing; face-to-face interviews; using visual aids; and enumerator training.

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Appendix 1: Scenario that was read to the farmers

The government is considering providing various packages to improve maize yield to farmers, based on what they are willing to pay for their chosen package.

This package consists of combinations of:

i) different maturing maize varieties
ii) maize varieties which are either drought or disease resistant
iii) different types of fertiliser

I will be showing you different packages of different prices for you to choose the combination you for which you will be willing to pay for that particular price.