ESTIMATING DEMAND VIA EXPERIMENTS IN THE AGRICULTURAL-NUTRITION SPACE

By

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ABSTRACT

Micronutrient malnutrition affects two billion individuals worldwide, especially developing countries' rural populations where the majority of food intake is from staple crops. The adoption and consumption of biofortified crops, which are staple food crops conventionally bred to have higher levels of micronutrients and minerals, is one agricultural-nutrition intervention being implemented to increase micronutrient intake. In this dissertation, I utilize experimental auctions to estimate consumer and farmer demand, measured via willingness-to-pay (WTP), for two biofortified staple food crops, rice and beans. I assess how information, farmer aspirations, and the difference in the experimental quantity used versus respondents' intended purchase quantity impact demand estimates. Findings can be used by implementers, extension agents, and agro-dealers regarding how best to increase demand for biofortified crops.

Chapter one examines the effects of nutrition information on rural Bangladeshi consumers' WTP for two ways to increase zinc intake through rice. I assess zinc intake via low-milling and biofortification of rice with increased zinc content, which is also low-milled to retain maximum zinc content. Results indicate that with information, consumers are willing to pay a premium for zinc biofortified rice compared to non-biofortified rice, when milled at the same level. However, results confirm Bangladeshi consumers' strong preference for high-milled rice, as they discounted low-milled rice even after receiving information on the nutritional benefits of biofortified or low-milled rice. Therefore, given current consumer preferences, other micronutrient intake interventions, beyond biofortification, should be explored.

In chapter two, I examine the role of farmer aspirations on WTP for biofortified bean seed, whose health benefits are considered a medium-term investment. Specifically, I assess if farmers classified as being high aspiring have a higher WTP for biofortified bean and if they

respond differently, as evidenced by their WTP, to nutrition and cooking quality information shared about the various bean seed types, via three rounds of bidding. I find that compared to the non-biofortified benchmark seed type, farmers are willing to pay a premium for biofortified bean seed when information is shared. Therefore, biofortified bean seed should be labeled, and nutrition and consumption information should accompany the seeds to elicit maximum demand. So, for initial roll-out, this study recommends targeting farmers that have achieved above a primary school education, that farm larger total land area across all crops, have greater assets, participate in farmer field days, are part of a savings group, and are members of a religious group as these characteristics distinguish high aspiring farmers.

Chapter three investigates if, and to what degree, varying bid quantity in WTP elicitation impacts per-unit WTP via a non-hypothetical field experiment using rural Zimbabwean farmers. I compare the status-quo approach of small, pre-fixed experimental quantities for bid elicitation versus an innovative approach where the experimental quantity is matched to each respondent's intended purchase quantity (IPQ). Farmers were randomly assigned to either a fixed quantity group (FQG) where they bid for 2kgs of seed or a variable quantity group (VQG) where their experimental quantity was matched to their IPQ. I find that the per-unit WTP is significantly biased upward when bids were elicited using a fixed quantity compared to farmers' IPQ. This bias was significantly higher for novel (biofortified bean) seeds. I find evidence that this bias in WTP is due to respondents' IPQ being above the fixed experimental quantity used. These results point to the need for researchers to critically consider the experimental quantity when designing input-based producer WTP studies. The estimated high WTP based on a small experimental bid quantity can have major implications for companies launching new products and estimating effective demand for agricultural inputs as well as governments setting input subsidy prices.

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CHAPTER 1. RURAL BANGLADESHI CONSUMERS' (UN)WILLINGNESS TO PAY FOR LOW-MILLED RICE: IMPLICATIONS FOR ZINC BIOFORTIFICATION

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1. Introduction

Micronutrient malnutrition, also known as 'hidden hunger', is one of the most prevalent forms of malnutrition, estimated to affect two billion individuals worldwide prior to the COVID-19 pandemic (FAO et al., 2015). Hidden hunger disproportionally affects developing countries' rural populations as a majority of food intake is from staple crops. Zinc deficiency, a main form of hidden hunger, is a severe public health problem in Bangladesh with 30% of the population at risk of inadequate zinc intake (Wessells et al., 2012). Zinc is essential for proper physical and cognitive development in children and adults. Additionally, zinc is crucial for immune system development and resiliency, which decreases susceptibility to infections such as diarrhea and pneumonia, a leading cause of child mortality in the developing world (Black et al., 2013), and to viral diseases such as COVID-19 (Wessels et al., 2020). In Bangladesh, 57% of women-of-childbearing-age (WOCBA) and 45% of preschool-age children are zinc deficient (IPHN, 2014; Rahman et al., 2016).

Increased zinc intake can readily be attained by improved dietary quality that meets both caloric and nutritional requirements. However, much of the world cannot access or afford a diet of micronutrient-rich foods like fruits, vegetables, and animal-source foods. Pre-COVID-19 estimates suggest that 3 billion people could not afford a healthy diet (FAO et al., 2020). Even when these foods are available, they are often allocated to men or adolescent boys in the household (Herrador et al., 2015), even though WOCBA and children under five have higher biological micronutrient needs (Black et al., 2013). To date, the majority of interventions used to address hidden hunger have been food fortification (during the processing stage) and supplementation, though with limited success in rural areas (Narayan et al., 2019).

In this paper we assess rural Bangladeshi consumers' willingness-to-pay (WTP) for two alternative low-cost rice products intended to improve zinc intake: (1) zinc biofortified low-milled rice and (2) non-biofortified low-milled rice. We measure the impact of varying amounts of information for these two products on 576 consumers' WTP by conducting economic experiments using the Becker-DeGroot-Marschak (BDM) mechanism.

Bangladeshi consumers prefer eating high-milled rice produced from paddy that is first parboiled. These processes—parboiling and high milling—produce rice with reduced zinc content (see section 2.2). Low milling protects rice grain zinc content from being removed. Biofortification further enhances the zinc content of rice,[1] but to maintain the majority of zinc content after undergoing parboiling, it also requires low milling. In our experiments, we provided study participants information about the nutritional benefits of low-milling and zinc biofortification. By evaluating the two nutritious low-milled products—zinc biofortified and non-biofortified rice—relative to high-milled rice, we are able to evaluate the viability (or lack thereof) of low-milled rice and zinc biofortified rice's consumer demand as a way to increase zinc intake. Results of our experiments confirm rural Bangladeshi consumers' strong preference for high-milled rice. Relative to high-milled rice, consumers discounted the two more nutritious low-milled rice products by 10%, even after receiving information on low milling benefits. Among the two discounted low-milled products (biofortified and non-biofortified), consumers

[1] Biofortified zinc rice has 75% more zinc than non-biofortified rice varieties at the same milling level (Andersson, 2017).

were WTP a 4.6% premium for zinc biofortified rice compared to non-biofortified rice after receiving zinc biofortified rice nutrition benefits information. However, this premium is still not sufficient to compensate for the steep discount consumers placed on low-milled rice. Since low milling is necessary to preserve the nutritional value of zinc biofortified rice, the results of this study indicate that increasing zinc intake through consumption of low-milled rice will require focused and strategic investments by the government and others to change consumer perceptions of and preferences for low-milled rice.

This paper makes several important empirical contributions to the literature. First, we measure consumer demand for a zinc biofortified crop and its invisible zinc trait. While numerous studies have explored the acceptance of and WTP for biofortified foods, most have been for visible traits, namely vitamin A biofortification which results in a change of color (Chowdhury et al., 2011; De Groote et al., 2011; Oparinde et al., 2016A). Fewer studies have elicited consumer WTP for invisible crop traits (credence goods), and primarily examined iron biofortified crops (Oparinde et al., 2016B; Banerji et al. 2016). An exception is Valera et al.'s (2019) study, which estimated WTP for zinc rice seed, but from producers' perspective as a production input rather than a consumption good. To our knowledge, no study has evaluated consumer WTP for the zinc trait in any crop and the majority of work on rice in Bangladesh has focused more on producer decision-making (Spielman et al., 2017; Ortega et al., 2019; Bashar et al., 2019), relative to consumer preferences. This paper contributes to filling this gap and pushes forward consumer-focused research on an important food crop in Bangladesh.

Another contribution of this study is the focus on WTP for processing techniques where the main objective is to improve nutritional content. A variety of WTP studies regarding food processing have been conducted; however, the focus is often on consumer interest in processing that preserves food attributes (Olsen et al., 2010), or enhances food safety (Ortega et al., 2011). One exception to this is a recent study by Chowdhury et al. (2021) that implemented a WTP experiment for fortified rice in Bangladesh. Additional research has been done on WTP for value-added products. Specific to rice, the Africa Rice Center has researched consumer demand for improved processing techniques (such as parboiling, milling, and grading), but the focus has been to increase the local rice quality and raise its competitiveness against imported rice (Demont and Ndour, 2015).

This paper is organized as follows: Section 2 provides a background on zinc biofortified rice and rice processing practices in Bangladesh, Section 3 describes the study's conceptual framework, and Section 4 shares data and sample descriptive statistics. Estimation strategies, empirical models used, and analysis results are described in Section 5. Section 6 concludes and discusses this study's policy implications.

2. Background

2.1 Rice in Bangladesh and Zinc Biofortified Rice

Rice (*Oryza sativa* L.) is the staple food crop in Bangladesh contributing 62% of daily calories (BBS, 2017). It is consumed at least twice daily. An important agricultural crop, the majority of rice (~96%) is sourced domestically (FAO, 2019) as it covers 75% of all cropped land in the country (BBS, 2017).

Biofortification, the breeding of staple food crops to improve nutritional content, is now considered a proven and scalable strategy to address hidden hunger.[2] Biofortified crops are bred to have the same agronomic and consumption attributes as the most popular varieties in a given agro-ecological zone (Bouis and Saltzman, 2017). For a discussion of yield and input costs of

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[2] Biofortification can be through conventional and transgenic breeding methods. For zinc rice in Bangladesh, conventional breeding methods were used.

biofortified zinc rice, see Appendix A.1. In a global prioritization index for biofortified crop development and delivery, Bangladesh ranked first for zinc biofortified rice suitability based on the country's production and consumption of rice in addition to their zinc deficiency status (Herrington et al., 2019). Zinc biofortified rice was introduced in Bangladesh in 2013 and delivers 75% more zinc content than common rice varieties (28 μg/g and 16 μg/g, respectively), at the same milling level (Andersson, 2017).[3] Zinc rice can provide up to 60% of daily zinc needs when processed and cooked using typical Bangladeshi consumption patterns (Andersson, 2017).

Eight zinc rice varieties have been developed through partnership between CGIAR's HarvestPlus Program, the International Rice Research Institute (IRRI), the Bangladesh Rice Research Institute (BRRI), and the Bangabandhu Sheikh Mujibur Rahman Agricultural University and have been delivered throughout almost the entire country (Bashar et al., 2019). To date, much effort around zinc biofortified rice has focused on farm side production. However, as plant breeding of new varieties and delivery of currently released zinc biofortified varieties expand, the focus has shifted to understanding consumer demand and market-based approaches to reach the non-farm zinc deficient population. Production can enter the market in one of two ways –as marketable surplus or as a differentiated product grown specifically for sale to capture a price premium. This study's results will shed light on whether a price premium for biofortified rice exists which can serve as a demand-pull strategy for producers to cultivate more land under biofortified rice.

While not examined in this paper, a likely additional cost passed to the consumer, beyond the production point, is certification and/or quality checks of the zinc credence good in

[3] See Appendix A.2 for a discussion of zinc content in other commonly consumed foods in Bangladesh.

biofortified zinc rice and its differentiation throughout the value chain (Banerji et al., 2016; Gabriel and Menrad, 2017). This certification can come via a third-party company or government which would test rice for claim of biofortification (e.g., PAS 233:2021 by BSI (2021)). Further, these testing results must be communicated to final consumers through signaling like product labeling. The costs of these requirements are currently unknown but should be evaluated in light of this study's WTP findings.

2.2 Typical Processing Techniques and Nutrition Retention

Processing impacts the degree of zinc retention in rice grain. Rice is harvested as paddy which consists of a husk layer covering the caryopsis (brown rice). Typically, the husk is removed to produce brown rice. The brown rice is milled at various levels (degrees) to remove outer layers of the caryopsis and eventually the aleurone layer to produce white rice (Muthayya et al., 2014; IRRI, 2019). In Bangladesh and other regions of South Asia and West Africa, paddy rice undergoes an additional step of parboiling before being milled. Parboiling involves soaking and steaming paddy rice, at different temperatures, which can reduce the number of broken grains that occur during milling. Parboiled rice is also preferred in Bangladesh due to its longevity (less spoilage), digestibility, and reduced stickiness (Jaim and Hossain, 2012). While zinc is contained in the endosperm of the grain and, therefore, is mostly protected during milling, this is not the case if paddy rice is first parboiled (Taleon et al., 2022). During parboiling, zinc moves from the endosperm towards the kernel bran, making it more vulnerable to removal during milling (Taleon et al., 2020).

While less-milled rice is often consumed in rural areas due to its lower costs, high-milled (white) rice is the most popular rice in urban areas (Custodio et al., 2016) and even those eating less-milled rice prefer to eat white rice (GAIN, 2016). In a recent study conducted in

Bangladesh, zinc concentration was measured for parboiled rice at the low-milling level of 8% (to remove most of the pericarp and germ), and the highest milling level of 16% which produces white rice. The analysis showed that the low-milled grain had up to 77% more zinc than the highly milled grain and when combining the zinc content increase through biofortification and low-milling, biofortified low milled rice had up to 156% higher zinc content than non-biofortified high-milled rice (Taleon et al., 2022). In addition to zinc loss, other vitamin and micronutrients are also lost during a high degree of milling (Muthayya et al., 2014).

The traditional rice milling methods in Bangladesh, the *dheki* hand method or the Engelberg machine mills grain to approximately the 7.5% level. However, automatic rice mills are increasing in number throughout the country and traditional mills are disappearing as it becomes less expensive to send grain to automatic rice mills (Reardon et al., 2014). The automatic rice facilities mill upwards of 16% and double-polish the grain, which while increasing the rice grade and price premium (Khan and Murshid, 2018) produces rice with reduced nutritional content.

3. Methodology

3.1 Experimental Design and Conceptual Framework

This study's experiment is designed to assess consumers' WTP for rice grain with increased zinc content and to assess whether the WTP for this nutrition trait differs by the two approaches of increasing zinc content—low-milling processing techniques versus biofortification plus low-milling.[4] This study tests these differences with and without information on zinc nutritional benefits associated with biofortification and low-milling. Two rice varieties representing non-biofortified (NB) rice (BRRI dhan28) and biofortified (B) rice (BRRI dhan42)

[4] The 'biofortification plus low milling' approach is henceforth referred simply as 'biofortification' for brevity.

are used in this study.[5] To retain nutritional value, the biofortified rice is milled at 7.5%, which represents low-milling (LM) level. Though adding a zinc biofortified rice milled at 15% seems like a natural addition to the experiment, we did not present this grain option to consumers due to the chemical reaction that occurs during parboiling; milling at 15% removes much of the added genetic zinc content bred into the grain. The non-biofortified rice is milled at two levels – 7.5% (LM) and the more popular 15% (high-milling level, HM). Thus, the experiment includes three rice grain types, consisting of two different rice varieties and two levels of milling—non-biofortified BRRI dhan28 at high-milled level (NBHM), non-biofortified BRRI dhan28 at low-milled level (NBLM), and biofortified BRRI dhan42 at low-milled level (BLM). The experiment follows a between-subject design and consists of three groups—Treatment group 1 (TG1) that received information on zinc biofortified rice, Treatment group 2 (TG2) that received milling nutrition information, and a control group that received no information.

The WTP experiments elicit information regarding respondents' WTP for the aforementioned rice grain types. We utilize the Becker-DeGroot-Marschak (BDM) (Becker, DeGroot, and Marschak 1964) method, an incentive-compatible single response procedure used in experimental economics to measure consumer WTP. In the BDM mechanism, a respondent submits a bid for a good being auctioned, 1 kilogram of each rice grain type in this study. The respondent does not bid against others as in a traditional auction, but against a random market price drawn from a distribution established *ex-ante*. If the respondent's bid is greater than the market price drawn, then s/he pays the randomly drawn price and receives the good. Alternatively, if the respondent's bid is less than the market price, no transaction occurs.

[5] BRRI dhan28 is the most popular non-biofortified rice grain in Bangladesh for the study season so it serves as the experiment's benchmark grain. BRRI dhan42 was selected as the biofortified rice used as it most closely resembles the grain characteristics of BRRI dhan28 (Tiongco and Hossain, 2015).

The respondent's true WTP for a unit of the good being auctioned is defined as the price that induces a utility indifference between winning and not winning the good. Rational behavior under the BDM mechanism is for the respondent to place a bid equal to their WTP (Lusk and Shogren, 2007). In the case of individuals bidding on multiple goods, as in our case, one of the bids is selected at random to be the binding bid such that only one good's bid is compared against a market price for that particular good. The difference in bids between BDM experiments with and without information reveals the premium, or discount, due to the different rice grain attributes as perceived by the consumer.

The BDM elicitation method varies between either endowing respondents with a good and having them bid to upgrade that good, known as "endow and upgrade", or asking participants to offer full bids for a particular good (Lusk and Shogren, 2007). We use the full bidding method as we are interested in capturing total WTP for each product. At the start of the study, each participant received a participation fee of 500 Bangladesh taka (BDT), the equivalent of US $6.04.[6] As we included participation fees, there is a possibility of inflated WTP bids, though literature suggests mixed effects of significance (Corrigan and Rousu, 2006; Banerji et al., 2017).

Prior to the experiment, enumerators explained the BDM procedure one-on-one to respondents. To ensure understanding, a practice round was conducted with common crackers. Respondents were allowed to ask questions on the experimental procedure. Following this, if the respondent was randomly assigned to either of the treatment arms, they listened to a respective one-minute informational clip on zinc nutritional enhancement via zinc biofortified rice (TG1) or via decreased milling practices (TG2). Those not randomly assigned to TG1 or TG2, served as

[6] The exchange rate during the experiment was 82.73 BDT to 1 USD. The participation fee is approximately equal to a daily wage for the study locations plus the average price for one kilogram of rice.

the control group. To mimic market settings, in all groups, one kilogram of the three uncooked rice grains (NBHM, NBLM, and BLM) were placed in randomized order before the respondents in equal sized clear containers without labels but with different colored lids: red, orange, and green. The invisible zinc attribute cannot be detected in the BLM rice, but low-milled rice is easily identifiable by its brown color compared to high-milled rice which is white. In TG1, both the audio clip and the enumerator identified the BLM rice from the NBLM and NBHM rice. Similarly, in TG2, the audio clip and the enumerator identified the two low-milled rice grains. Consumers could touch and smell grains during the experiment.

In TG1 and TG2, after listening to the audio clip, respondents submitted bids for each rice type but told only one bid would be binding. In the control group, no audio clips/information was provided, so respondents submitted bids after completing the practice round. The randomly selected market price distribution, uniform between 28-50 BDT/rice kg, was based on local market prices. Respondents were not informed of this price range, simply that prices were based on current prices from their local market. Respondent bids were not censored. To select the binding bid, participants drew one of three colored die (red, orange, or green) from an opaque bag which corresponded to each of the three rice products' lid colors. Next, the participant drew one "coin" from another opaque bag of market prices. The enumerator compared the respondent's bid to the market price drawn and transactions were carried out according to BDM rules. After completing the experiment, respondents completed a questionnaire.

3.2 Empirical Strategy

Regression analysis is used to examine the information treatment effect on consumers' WTP total and marginal bids. Since the experiment was between subjects, we estimate the treatment effect via Pooled Ordinary Least Squares (POLS) method.[7] Further, we had no zero bids and less than 1% of bids submitted were outside of the market price range (28-50 BDT) used. Following Canavari et al. (2019), as the share of bid observations outside of the market price range is trivial, resulting estimates between using Tobit versus OLS do not diverge. Therefore, for ease of interpretation, we use OLS for analysis and do not censor bid observations. Equation 1.1 is a parsimonious specification intended to estimate only the information treatments' effect in explaining WTP bid variation ($\text{i.e., coefficient } \beta_3$). We test the robustness of the treatment effect size by incorporating control variables ($\boldsymbol{X_i}$) in equation 1.2, and the interaction of the treatment with a subset of control variables (vector $\boldsymbol{Y_i}$) in equation 1.3. Our specification for the linear panel data model used is:

$$Total\ Bid_{ij}^{t} = \alpha + \beta_1 P_j + \beta_2 T^t + \beta_3 (P_j * T^t) + u_{it} \qquad \text{for } t\text{=1, 2} \qquad (1.1)$$

$$Total\ Bid_{ij}^{t} = \alpha + \beta_1 P_j + \beta_2 T^t + \beta_3 \left(P_j * T^t\right) + \boldsymbol{\eta X_i} + u_{it} \qquad \text{for } t\text{=1, 2} \qquad (1.2)$$

$$Total\ Bid_{ij}^{t} = \alpha + \beta_1 P_j + \beta_2 T^t + \beta_3 \left(P_j * T^t\right) + \boldsymbol{\eta X_i} + \boldsymbol{\gamma}(T^t * \boldsymbol{Y_i}) + u_{it} \quad \text{for } t\text{=1, 2} \quad (1.3)$$

where Bid_{ij}^{t} is the WTP bid for consumer *i* for the rice product *j* under information treatment *t*. Each of these three equations are estimated separately for the two information treatments—t=1 represents information on zinc biofortified rice and t=2 represents information on low-milling. Variable T^t delineates individuals randomly assigned to treatment group *t* (=1, =2) and the control group (=0). P_j is an indicator of nutritionally enhanced rice product. In the case of the zinc biofortification treatment (t=1), we compare BLM (*Pj*=1) to the NBLM (*Pj*=0). For the information on low-milling (t=2), we compare NBLM (*Pj*=0) to the NBHM (*Pj*=2). The $\boldsymbol{X_i}$ represents a vector of respondent characteristics and experiment controls. $T^t\ \boldsymbol{x}\ \boldsymbol{Y_i}$, is a vector of

[7] As robustness checks, random effects and panel Tobit analysis were conducted and results hold.

interaction terms between the treatment variable and selected respondent characteristics based on *a priori* hypotheses and previous literature (De Groot et al., 2011; Diagne et al., 2017; Zossou et al., 2022; Chowdury et al., 2016; Valera et al., 2019). Finally, u_{it} is the idiosyncratic error term. Robust standard errors were clustered at the participant level for equations 1.1-1.3.

Next, we use regression analysis to examine WTP premiums/discounts by comparing (1) BLM versus NBLM rice (under treatment, t=1), and (2) NBLM versus NBHM rice (under t=2). The value of Equation 2, below, lies in identifying additional determinants of premiums/discounts of BLM and NBLM, beyond the information treatment itself, which can be used for nutritional awareness campaign targeting to maximize finite resources (time, money, etc.). Our OLS estimator for WTP premium/discount can be represented as:

$$MargBid_i^t = \alpha + \beta T^t + u_{it} \qquad \text{for } t\text{=1, 2} \qquad (2.1)$$

$$MargBid_i^t = \alpha + \beta T^t + \boldsymbol{\eta X_i} + u_{it} \qquad \text{for } t\text{=1, 2} \qquad (2.2)$$

$$MargBid_i^t = \alpha + \beta T^t + \boldsymbol{\eta X_i} + \boldsymbol{\gamma}(T^t * \boldsymbol{Y_i}) + u_{it} \qquad \text{for } t\text{=1, 2} \qquad (2.3)$$

where $MargBid_i$ is estimated as individual i's difference in WTP bids for a nutritionally enhanced product (either BLM rice in case of t=1 or NBLM rice in case of t=2) against its counterfactual (i.e., NBLM rice in case of t=1 or NBHM rice in case of t=2). If the resulting coefficient is positive, it represents a positive marginal WTP or premium for BLM compared to NBLM rice. If the resulting estimates coefficient is negative, it represents a negative marginal WTP or discount for BLM compared to NBLM rice. The same holds for NBHM versus NBLM rice. Like in equations 1.1-1.3, the $\boldsymbol{X_i}$ represents a vector of respondent characteristics and experiment controls and $T^t \boldsymbol{x} \boldsymbol{Y_i}$, is a vector of interaction terms between the treatment variable and select respondent characteristics. Finally, u_{it} is the idiosyncratic error term. In these models, coefficient β measures the effect of the information treatment on consumers' WTP premium (or discount) for the nutritionally enhanced trait (either zinc biofortification or low milled rice). Robust standard errors were clustered at the block level for equations 2.1-2.3.

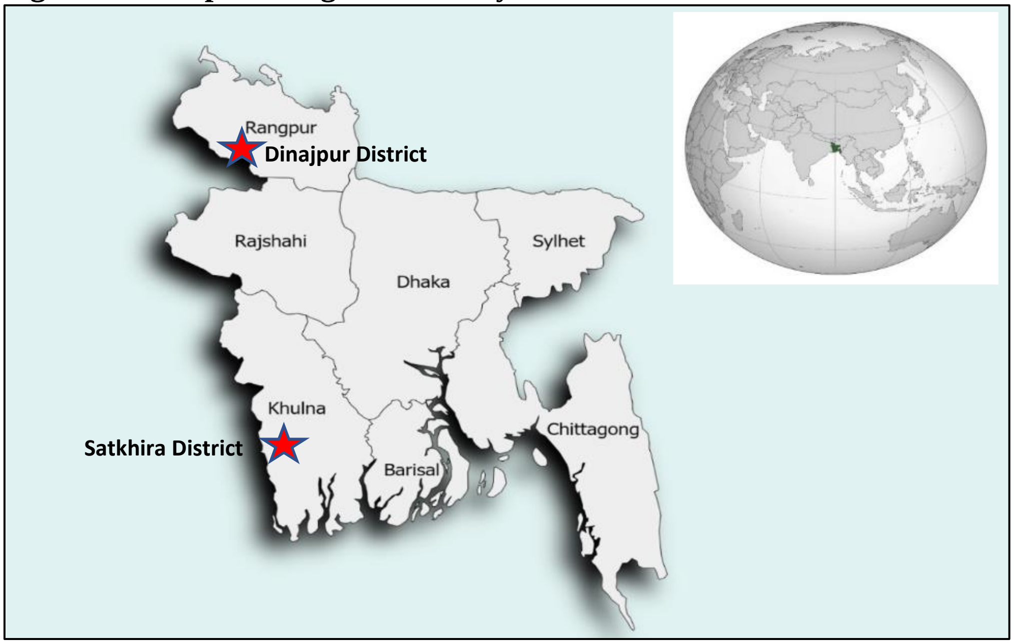
3.3 Data

Data was collected through collaboration with the CGIAR's HarvestPlus Program and BRRI. Ethical clearance was obtained prior to commencing field work.[8] Dinajpur and Satkhira districts were specifically selected as study locations representing a surplus rice producing region with many automatic rice mills and a net rice purchaser with few automatic rice mills, respectively. A total of 576 rice consumers, split evenly between Dinajpur district in the north and Satkhira district in the south, participated in the study.[9] Study participants represent rural households that purchase rice from the market. For a detailed description of sample selection process, see Appendix A.3.

[8] This study complies with Institutional Review Board (IRB) guidelines of the International Food Policy Research Institute (IFPRI) and the Memorandum of Understanding with the IFPRI Agriculture Policy Support Unit in Dhaka which allows the Ministry of Agriculture to approve research for local clearance; additional Bangladesh IRB approval was not required. This study's approval:IFRI IRB #00007490; BRRI Agreement #2018H8348.BRR.

[9] Within Dinajpur, data collection occurred in Parbatipur, Birganj, and Sadar upazilas and in Satkhira, Kaliganj, Kolaroa, and Satkhira Sadar upazilas.

Figure 1.1: Map of Bangladesh Study Locations



*Sources: mapsland.com, paintmaps.com

The study targeted the main household decision-maker for rice purchases. In our sample, respondents are 93% male and, on average, 42 years old (Table 1.1). Approximately half of the respondents' main income source is farming, and on average, they have five years of formal education. On average, the per-capita household consumption of rice is 150 kg per year. Respondents vary in the frequency of rice market purchases – 12% purchase rice on a daily basis while 34% of respondents purchase on a monthly basis, or less frequently. Additional sample statistics are in Table 1.1.

Table 1.1: Sample characteristics and balancing test

Variable	Sample Mean (Std Deviation)			P-value of Group Mean Comparison
	Control (N=192)	Treatment 1 (Biofortification) (N=192)	Treatment 2 (Low-milling) (N=192)	
Male (%)	94.8 (22.3)	92.7 (26.1)	92.7 (26.1)	0.638
Household Head (%)	84.9 (35.9)	86.5 (34.3)	84.9 (35.9)	0.883
Age	41.2 (12.7)	41.9 (13.3)	41.4 (13.3)	0.853
Years of formal education	5.1 (4.8)	5.1 (4.7)	5.3 (4.8)	0.870
Main occupation: farming[1] (%)	52.6 (50)	51.6 (50.1)	52.6 (50)	0.973
Household size	4.8 (1.6)	4.7 (1.7)	4.8 (1.6)	0.934
No. of children under 5 y.o. in HH	0.4 (0.6)	0.4 (0.6)	0.4 (0.6)	0.585
No. of WOCBA[2] in HH	1.5 (0.8)	1.4 (0.7)	1.5 (0.8)	0.515
HH's per-capita yearly rice consumption (in 10kg)	15 (3.9)	15.3 (4.1)	15.2 (3.6)	0.747
HH purchases rice more than 1/week (%)	29.2 (45.6)	33.3 (47.3)	31.8 (46.7)	0.6750
HH purchases rice 1/week or 2/month (%)	37.5 (48.5)	30.7 (46.3)	35.4 (48.0)	0.3615
HH purchases rice 1/month or less often (%)	33.3 (47.3)	35.9 (48.1)	32.8 (47.1)	0.788
HH's per-capita monthly income (in BDT)	2120.7 (1642.1)	2053.9 (1484.5)	2070.1 (1590.8)	0.910
Zinc biofortified rice awareness (%)	8.3 (27.7)	9.9 (29.9)	13 (33.7)	0.311

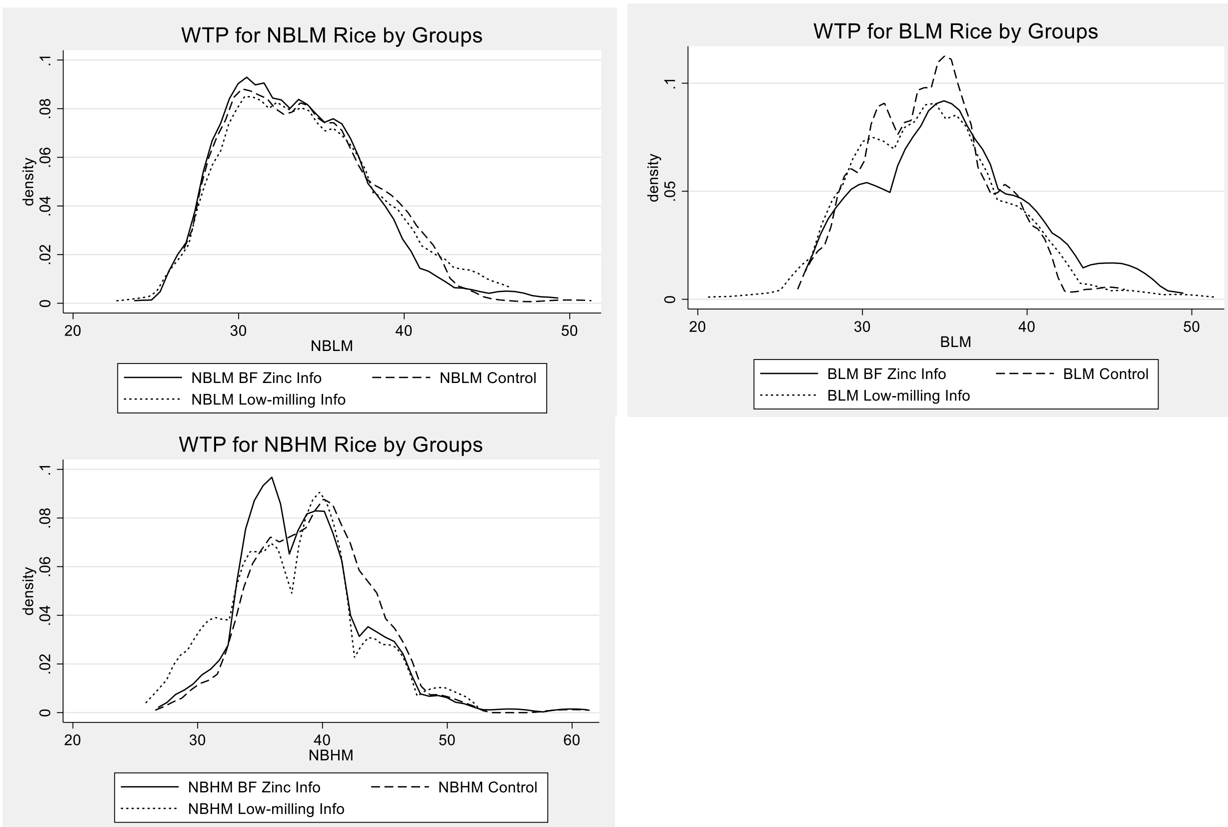
Source: author's data.
Note 1: Category includes self-employed farmers and farm laborers on another's farm.
Note 2: WOCBA: females ages 15–49, as defined by the WHO.

4. Results and Discussion

4.1 WTP for Nutritional Traits

The distribution of WTP bids by control and treatment groups is presented in Figure 1.2.

Figure 1.2: Kernel density for (1) NBLM Rice WTP, (2) BLM Rice WTP, and (3) NBHM Rice WTP



The mean bids for the three products suggest a strong preference for NBHM, which is currently the most preferred type of rice grain consumed. Under all three scenarios, consumers' WTP for 1 kg of NBHM is about 4–5 BDT more than the other two nutritionally enhanced rice grains (Table 1.2). In comparing WTP bids, we find consumers place a 14% premium ($p<0.01$) on NBHM rice compared to NBLM rice and a 13% premium ($p<0.01$) on NBHM rice when compared to BLM rice when no information is shared about milling's impact on nutrition. Further, when information is shared about the negative effect of milling on nutrition, the premium for the preferred NBHM grain declines to 9.9% (p-value<0.01) compared to the NBLM grain (translating to a treatment effect size for milling information of 4.1%) and to 9.4% ($p<0.01$) compared to BLM grain (translating to a treatment effect size for milling information of 3.8%).

Results also show that without information on the zinc biofortified variety, there is a small difference ($p<0.10$) in consumers' WTP bid for the two low-milled rice—BLM and the NBLM such that a 1.1% premium exists for BLM rice. However, when information is shared on increasing zinc intake via zinc biofortified rice, consumers were willing to pay a 5.8% price premium for BLM rice over NBLM rice (p-value<0.01). Information on zinc biofortified rice increased WTP for BLM rice by 4.6% over NBLM. After sharing the information on zinc biofortified rice, consumers still discounted BLM rice relative to NBHM rice, but the discount reduced from 13.2% in the control group to 7.8% in TG1 (Table 1.2).

Table 1.2: Willingness to Pay (WTP) for rice types (BDT/1kg) and traits

	Rice type	Statistic	Control Group* (N=192)	Treatment 1: Zinc Biofortified Information (N=192)	Treatment 2: Milling Nutrition Information (N=192)
Mean WTP	Non-biofortified, low-milled variety (a)	Mean	33.8 $^{a, \lambda}$	33.5 $^{b, j}$	34.1 ^{c}
		SD	(4.1)	(4.2)	(4.4)
	Biofortified, low-milled variety (b)	Mean	34.2 $^{h, g, \lambda}$	35.5 $^{b, d, f, h}$	34.2 $^{d, e}$
		SD	(3.7)	(4.7)	(4.4)
	Non-biofortified, high-milled variety (c)	Mean	39.4 $^{a, g, i, \gamma}$	38.5 $^{f, j, \gamma}$	37.8 $^{c, e, i}$
		SD	(4.6)	(4.8)	(5.2)
WTP for traits	Nutrition (Zinc) via biofortified genetic trait (b-a)	BDT/1kg	0.4	1.9	
		SD	(2.9)	(4.1)	
		%	+1.1	+5.8	
	Nutrition (Zinc) via biofortified genetic trait (b-c)	BDT/1kg	-5.1	-3.0	
		SD	(3.0)	(4.8)	
		%	-13.2	-7.8	
	Nutrition via decreased milling (a-c)	BDT/1kg	-5.5		-3.7
		SD	(3.1)		(4.8)
		%	-14.0		-9.9
	Nutrition via decreased milling (b-c)	BDT/1kg	-5.1		-3.6
		SD	(3.0)		(4.3)
		%	-13.2		-9.4

Notes: (1) rice types in the control group were unknown (unlabeled) to respondents at bidding time. Zinc is an invisible seed trait so unless told, respondents could not differentiate the zinc biofortified variety, (2) numbers with matching English letters (a-j) denotes raw WTP bid differences significant at $p<0.01$, (3) numbers with matching Greek letters (λ, γ) denotes raw WTP bid differences significant at $p<0.10$, (4) SD=standard deviation.

Next, we examine the effect of the information treatment on consumers' WTP for the two nutritionally enhanced rice products. For biofortification information, we obtain the effect by keeping milling level constant and compare bids for control and TG1 groups for BLM and NBLM rice. We obtain the milling information effect by keeping the genetics constant and compare bids for the control and TG2 groups for NBLM and NBHM rice. Results for zinc biofortified low-milled rice are presented in Table 1.3 and for non-biofortified low-milled rice in Table 1.4. We find Bangladeshi consumers are WTP a significant premium for BLM rice after exposure to zinc biofortified rice information (TG1) when compared to NBLM rice. Analysis results match findings from mean WTP bids (Table 1.2) and show respondents are WTP a premium of 1.55 BDT for BLM rice compared to NBLM rice after receiving zinc biofortified rice information (represented by variable: received zinc biofortified info x BLM rice product), (Table 1.3). This estimated treatment effect is robust after controlling for consumer and experiment characteristics and interaction effects (columns 2 and 3, Table 1.3).

Further evaluating cross-effects of receiving zinc biofortified rice information and additional covariates, in column 3, we find positive WTP for each additional year of formal education attained by the respondent. This result outweighs the negative and significant impact on consumer WTP of respondents' formal education when no information is received (column 3).

Aside from information exposure cross-effects, respondents' bid increases with per-capita household monthly income and with each additional child in the household that is under five while bids decrease as respondents age (but only in column 3). Consistent with Hoffman (1993), those participating in morning sessions had a lower WTP for NBLM rice than those in afternoon sessions though counter to other studies findings (Demont and Ndour, 2015; Diagne et al., 2017).

Potentially, individuals do not feel rushed about their rice purchase in the morning knowing that if they do not "win" during the experiment, they still have time to purchase rice from the market while this may not be the case for afternoon session participants.

Turning now to the same models for NBLM versus NBHM rice (Table 1.4), we find that after receiving the information on low-milling nutritional benefits, Bangladeshi consumers' WTP for low-milled rice increased by BDT 1.78/kg. This estimated effect of the information treatment is statistically significant and robust across model specifications (Table 1.4).

Statistical differences in mean WTP bids between NBLM and NBHM rice without information, and mean WTP bids between NBHM rice with and without information, support findings in Table 1.2. Further evaluating cross-effects of receiving low-milling nutrition information and additional covariates, in column 3, we find negative WTP for NBHM rice as the respondent's household monthly per-capita income increases, which is counter to the effect of income when the respondent did not receive information. Aside from information exposure cross-effects, respondents' bid for NBHM rice decreases if they participated in the morning session.

Table 1.3: Consumers' WTP for biofortified rice: BLM versus NBLM WTP Results

	(1)		(2)		(3)	
Variables	Coeff.	Robust SE	Coeff.	Robust SE	Coeff.	Robust SE
Biofortified Rice Product (BLM)	0.385*	(0.208)	0.385*	(0.210)	0.385*	(0.211)
Received Biofortified (BF) Zinc Info	-0.297	(0.424)	-0.276	(0.418)	-0.871	(0.785)
Received BF Zinc Info * BLM Rice Product	1.552***	(0.363)	1.552***	(0.366)	1.552***	(0.367)
Socioeconomic						
Age	--	--	-0.023	(0.016)	-0.027*	(0.016)
Female	--	--	-0.370	(0.861)	-0.095	(0.884)
HH size	--	--	-0.062	(0.128)	-0.033	(0.125)
No. of children in HH ≤ 5 years	--	--	0.656*	(0.360)	0.736*	(0.438)
Years of completed education	--	--	0.011	(0.048)	-0.114*	(0.062)
Household per-capita monthly income	--	--	0.264*	(0.137)	0.416***	(0.158)
Main Occupation: Farming	--	--	-0.473	(0.390)	-0.420	(0.387)
Dinajpur District Resident	--	--	-0.107	(0.408)	-0.079	(0.410)
Household Rice Behavior						
Per-capita yearly rice consumption (in 10kg)	--	--	0.008	(0.055)	0.010	(0.055)
Purchases rice weekly or every two weeks	--	--	0.412	(0.504)	0.454	(0.504)
Purchases rice monthly or less often	--	--	-0.086	(0.522)	-0.322	(0.515)
Experiment Controls						
Felt hungry	--	--	0.133	(0.378)	0.195	(0.379)
Morning session	--	--	-1.087***	(0.388)	-1.04***	(0.382)
Cognitive						
Prior BF rice awareness	--	--	0.186	(0.649)	0.012	(0.991)
Received Zinc Biofortified Info Cross-effects						
* No. of children in HH ≤ 5 years	--	--	--	--	-0.219	(0.610)
* Household per-capita monthly income	--	--	--	--	-0.336	(0.268)
* Years of completed formal education	--	--	--	--	0.264***	(0.087)
* Prior awareness of BF rice	--	--	--	--	0.515	(1.297)
Constant (NBLM rice)	33.844***	(0.3)	34.786***	(1.385)	35.043***	(1.334)
R-Square	0.03		0.0805		0.1004	
Number of observations	768		768		768	
Number of respondents	384		384		384	

Note: *= p<10%, **=p-value <5%, ***=p-value <1%.

Table 1.4: Consumers' WTP for low-milled rice: NBLM versus NBHM WTP Results

	(1)		(2)		(3)	
Variables	Coeff.	Robust SE	Coeff.	Robust SE	Coeff.	Robust SE
Non-biofortified Low-milled Rice Product (NBLM)	-5.516***	(0.226)	-5.516***	(0.228)	-5.516***	(0.228)
Received Milling Nutritional Info	-1.568***	(0.501)	-1.520***	(0.505)	-0.145	(0.882)
Received Milling Info * NBLM Rice Product	1.776***	(0.415)	1.776***	(0.419)	1.776***	(0.420)
Socioeconomic						
Age	--	--	-0.016	(0.017)	-0.019	(0.017)
Female	--	--	-0.417	(1.002)	-0.642	(0.995)
HH size	--	--	0.042	(0.155)	0.038	(0.151)
No. of children in HH ≤ 5 years	--	--	0.228	(0.370)	0.575	(0.477)
Years of completed education	--	--	-0.066	(0.049)	-0.067	(0.071)
Household per-capita monthly income	--	--	0.223*	(0.140)	0.451**	(0.180)
Main Occupation: Farming	--	--	-0.466	(0.441)	-0.575	(0.444)
Dinajpur District Resident	--	--	-0.362	(0.448)	-0.427	(0.448)
Household Rice Behavior						
Per-capita yearly rice consumption (in 10kg)	--	--	-0.058	(0.063)	-0.052	(0.063)
Purchases rice weekly or every two weeks	--	--	-0.101	(0.526)	-0.226	(0.535)
Purchases rice monthly or less often	--	--	0.217	(0.529)	0.108	(0.528)
Experiment Controls						
Felt hungry	--	--	0.320	(0.435)	0.312	(0.430)
Morning session	--	--	-0.802*	(0.431)	-0.795*	(0.433)
Received Milling Info Cross-effects						
* No. of children in HH ≤ 5 years	--	--	--	--	-0.823	(0.677)
* Household per-capita monthly income	--	--	--	--	-0.486*	(0.263)
* Years of completed formal education	--	--	--	--	-0.007	(0.090)
Constant (NBHM rice)	39.359***	(0.331)	41.113***	(1.791)	40.756***	(1.785)
R-Square	0.2119		0.2327		0.2399	
Number of observations	768		768		768	
Number of respondents	384		384		384	

Note: Robust standard errors clustered at participant id level, *= p<10%, **=p-value <5%, ***=p-value <1%.

4.2 Determinants of Marginal WTP for Nutritious Rice

Next, we focus on the information treatment effect and other correlates on consumers' WTP premiums/discounts for the two nutritious products—zinc biofortified low-milled rice and non-biofortified low-milled rice. Columns 2 and 3 of Table 1.5 correspond to marginal WTP of BLM rice with NBLM rice as the base. Results indicate the presence of BLM rice premiums for subjects who received zinc biofortified information, female respondents, and respondents residing in Dinajpur district (the rice-surplus producing district). Also, the marginal WTP for BLM increases as household yearly per-capita rice consumption increases. The Dinajpur variable results is unexpected but potentially respondents residing in a rice-surplus producing region such as Dinajpur are exposed to different rice varieties/attributes in the local market compared to rice-importing regions and are therefore, more willing to try a new rice attribute.

Further, the marginal WTP for BLM rice is 0.11 – 0.12 BDT for each additional 10kg of household per-capita rice consumed (columns 2 and 3). An explanation of this could be that with the increase in rice quantity consumed, households become less risk averse and are willing to try new rice types, knowing that dislike it, they will likely be able to consume other rice types at their next meal(s). Another possible reason could be that as households consume more rice, they want variety in their rice type(s). The marginal WTP for BLM rice is negative if the respondent's main occupation is farming, and with every household child under five years of age (only column 3). Contrary to this, if the respondent received zinc biofortified rice information, we see a bid premium of 1.1 BDT for BLM over NBLM rice among respondents for each household child under five years of age (column 3). Likely, with no detectable difference in BLM and NBLM rice, in the absence of information, the respondent is focused on meeting household members' caloric needs. However, upon receiving information, the respondent likely values

BLM's nutrition aspect for their children's consumption and factors this into their WTP in addition to meeting pure caloric needs.

In the absence of information, consumers steeply discount NBLM rice compared to NBHM rice (Table 1.6). The marginal WTP for NBLM rice is positive for every additional household child under five years of age (columns 2 and 3). This finding is intuitive as the household is likely more focused on meeting household caloric needs first before addressing any specialty rice attributes, purchasing a larger quantity of what is perceived as lower quality grain (NBLM in the absence of information) instead of less quantity of a more expensive grain. Besides children in the household, the marginal WTP of NBLM is negative without the respondent receiving milling information. Cross-effects of covariates with the respondent receiving milling information show that a positive marginal WTP exists for NBLM rice over NBHM rice for each additional education year attained by the respondent, which is counter to the discount existing for NBLM rice with increased educational attainment when the respondent receives no milling information (column 3). One would expect education to be correlated with income and status in a community so as high-milled rice is the preferred rice for many reasons, a discount for NBLM rice with increasing education makes sense when no information is received. However, education likely allows one to better process and act on the nutrition information when shared. Further, NBLM rice is discounted as the respondent ages, when no information is received but only in column 3. This result is not surprising given the likelihood that income increases as one ages, and consumption preferences are solidified over time making a person less likely to deviate from his/her status quo with age. Furthermore, age is likely correlated with respect and consuming high-milled rice is considered a status symbol. Additionally, in both columns 2 and 3, NBLM rice receives a positive marginal WTP if the respondent felt hungry at the time of the experiment. This result follows expectations that if an individual is hungry, they are likely more focused on consuming a greater quantity of a perceived lesser good (NBLM rice without information) than consuming less of a higher priced food item. The inclusion as a control variable and findings of the ‘hungry’ variable is in line with previous studies which note that hunger can affect bidding behavior (Canavari et al., 2019; Zossou et al., 2022).

Table 1.5: Consumers' Marginal WTP for Biofortified Rice: BLM minus NBLM WTP Results

	(1)		(2)		(3)	
Variables	Coeff.	Robust SE	Coeff.	Robust SE	Coeff.	Robust SE
Received BF Zinc Info * BLM Rice Product	1.552***	(0.369)	1.528***	(0.367)	0.630	(0.543)
Received Zinc Biofortified Info Cross-effects						
* No. of children in HH ≤ 5 years	--	--	--	--	1.102*	(0.606)
* HH per-capita monthly income	--	--	--	--	0.324	(0.220)
* Years of completed education	--	--	--	--	-0.056	(0.083)
* Aware of BF rice prior to study	--	--	--	--	0.695	(1.262)
Marginal Effect of Information[1]	1.552***	(0.369)	1.528***	(0.367)	1.528***	(0.3582)
Socioeconomic						
Age	--	--	-0.006	(0.018)	-0.003	(0.018)
Female	--	--	1.668*	(0.832)	1.732**	(0.833)
HH size	--	--	0.129	(0.123)	0.104	(0.124)
No. of children in HH ≤ 5 years	--	--	-0.302	(0.333)	-0.836***	(0.301)
Years of completed education	--	--	-0.003	(0.051)	0.027	(0.052)
HH per-capita monthly income	--	--	-0.009	(0.148)	-0.156	(0.162)
Main Occupation: Farming	--	--	-1.272***	(0.357)	-1.31***	(0.358)
Dinajpur District Resident	--	--	0.729**	(0.326)	0.724**	(0.322)
Household Rice Behavior						
Per-capita yearly rice consumption (in 10kg)	--	--	0.117**	(0.050)	0.114**	(0.050)
Purchases rice weekly or every two weeks	--	--	0.508	(0.492)	0.566	(0.492)
Purchases rice Monthly or less often	--	--	0.441	(0.486)	0.483	(0.481)
Experiment Controls						
Felt hungry	--	--	0.466	(0.390)	0.491	(0.389)
Morning session	--	--	0.179	(0.305)	0.202	(0.310)
Cognitive						
Prior BF rice awareness	--	--	-0.203	(0.586)	-0.562	(0.718)
Constant (BLM minus NBLM rice)	0.385**	(0.188)	-1.977	(1.496)	-1.605	(1.442)
R-Square	0.0458		0.115		0.1285	
Number of observations/respondents	384		384		384	

Notes: Robust standard errors clustered at block administrative level, *= p<10%, **=p-value <5%, ***=p-value <1%. [1] The marginal effect for model 3 is the discrete change from base level of info=0.

Table 1.6: Consumers' Marginal WTP for Low-Milled Rice: NBLM minus NBHM WTP Results

	(1)		(2)		(3)	
Variables	Coeff.	Robust SE	Coeff.	Robust SE	Coeff.	Robust SE
Received Milling Info * NBLM Rice Product	1.776***	(0.352)	1.786***	(0.356)	-0.004	(0.677)
Received Milling Info Cross-effects						
* No. of children in HH ≤ 5 years	--	--	--	--	0.546	(0.707)
* HH per-capita monthly income	--	--	--	--	-0.059	(0.233)
* Years of completed formal education	--	--	--	--	0.329***	(0.088)
Marginal Effect of Information[1]	1.776***	(0.352)	1.786***	(0.356)	1.787***	(0.357)
Socioeconomic						
Age	--	--	-0.029	(0.019)	-0.034*	(0.018)
Female	--	--	0.421	(0.745)	0.423	(0.770)
HH size	--	--	-0.014	(0.128)	-0.012	(0.126)
No. of children in HH ≤ 5 years	--	--	0.866**	(0.394)	0.624*	(0.346)
Years of completed education	--	--	0.007	(0.048)	-0.161***	(0.048)
HH per-capita monthly income	--	--	0.02	(0.127)	0.087	(0.099)
Main Occupation: Farming	--	--	-0.046	(0.377)	0.042	(0.368)
Dinajpur District Resident	--	--	0.081	(0.391)	0.016	(0.352)
Household Rice Behavior						
Per-capita yearly rice consumption (in 10kg)	--	--	-0.033	(0.050)	-0.023	(0.052)
Purchases rice weekly or every two weeks	--	--	0.611	(0.539)	0.583	(0.536)
Purchases rice monthly or less often	--	--	-0.590	(0.459)	-0.728	(0.449)
Experiment Controls						
Felt hungry	--	--	0.96**	(0.377)	0.991***	(0.367)
Morning session	--	--	0.184	(0.370)	0.249	(0.344)
Constant (NBLM minus NBHM rice)	-5.516***	(0.221)	-4.742***	(1.698)	-3.884**	(1.673)
R-Square	0.0457		0.1068		0.1436	
Number of observations/respondents	384		384		384	

Notes: Robust standard errors clustered at block administrative level, *= p<10%, **=p-value <5%, ***=p-value <1%. [1] The marginal effect for model 3 is the discrete change from base level of info=0.

5. Policy Implications and Conclusion

Zinc deficiency is a severe public health problem in many parts of the world, including Bangladesh (Wessells et al., 2012) and, to date, interventions such as food fortification and supplementation have had limited success, especially in rural areas (Narayan et al., 2019). Efforts to address dietary zinc deficiency have focused on finding low-cost, scalable alternatives. Two such alternatives recently being promoted in Bangladesh are zinc biofortification of rice (an invisible trait) and low-milling that gives rice grains a distinctive light brown color (visible trait). This visible trait sets low-milled rice apart from the culturally preferred highly-milled white rice grain (Custodio et al., 2016; GAIN, 2016). Given the invisibility, and therefore credence aspect of zinc biofortification and a strong dislike for a visible trait (i.e., light brown color) associated with low-milled rice, any efforts to increase the consumption of these products will need to raise consumer awareness through information campaigns. This paper addresses the policy relevant question on the effect of providing nutrition information on consumer demand for these two nutritious rice products.

Through experiments we (1) estimate the impact of providing nutrition information on consumers' WTP for zinc biofortified low-milled (BLM) rice grain and non-biofortified low-milled (NBLM) rice grain, and (2) assess additional determinants of marginal WTP for these zinc-dense rice products to aid nutritional awareness campaign targeting efforts.

Results suggest a positive nutritional information effect on consumers' WTP for nutritious rice compared to less nutritious alternatives. In the control group, there was an expected large and significant difference in the mean bid price for NBLM rice compared to non-biofortified high-milled (NBHM) rice at 33.8 BDT/rice kg and 39.4 BDT/rice kg, respectively, confirming that high-milled rice is preferred by consumers. Without receiving information on nutritional benefits of low-milling, the mean discount for low-milled rice ranging from 5.1-5.5 BDT/kg (or 13-14% discount). However, when information on higher nutrition (zinc) content through low-milling was provided, the discount between the high-milled rice and the two low-milled varieties decreased to about 9-10%, translating to a significant low-milling information treatment effect size of 1.5-1.78 BDT, or 3.8-4.1%.

Findings of this study suggest that to increase consumption of these two high-zinc rice products, awareness campaigns are needed to (1) educate consumers about zinc deficiency and its health and economic impacts and (2) inform consumers about low-cost food products to increase zinc intake, especially for those consumer groups which cannot afford and/or access zinc-rich foods. We acknowledge the impact of nutrition related information finding is based on individual-level experiments, which may not necessarily be scalable.

Since there are no documented additional costs to produce biofortified rice, a key finding of this study is that increasing zinc intake through biofortified low-milled rice consumption could be a viable solution for rural households, especially if the households are already consuming low-milled rice. This is evidenced by individuals responding positively to information on the benefits of zinc biofortified rice compared to non-biofortified rice when milled at the same level. The effect size of zinc biofortified rice information was an increase in consumer WTP by 1.55 BDT (or 4.6% increase in WTP) for one kilogram of BLM rice compared to NBLM rice. However, the positive biofortified zinc rice information effect is tempered by the findings of strong consumer preference for high-milled rice, which is shown in our results by the 3.0 BDT discount placed on BLM even after receiving nutrition information on zinc biofortification.[10] Given this finding, increasing zinc intake through consumption of zinc

[10] We recognize there could be scope to further reduce this discount if consumers are informed about low milling benefits and zinc biofortification. In an experimental setting, this could be assessed by including a fourth treatment

biofortified low-milled rice will likely take a focused, strategic effort by the government and/or health-related NGOs to change perceptions of low-milled rice in a country that generally prefers high-milled white rice. Such efforts will become more important as the ongoing proliferation of automatic rice mills in Bangladesh continue making high-milled rice less costly.

For effective resource allocation, results indicate initial consumer awareness efforts for zinc biofortified rice should begin in rice-surplus producing regions as they seem to respond to nutritional information.[11] Additionally, nutritional campaigns should target non-farm workers, women, families with children under five years old, and individuals with higher levels of formal education as they are responsive to zinc biofortified rice information and hence are more likely to be first adopters. Similarly, to increase low-milled rice demand, campaigns are essential to any outreach efforts and should target families with young children, younger, and more educated individuals.

Future research can include consumer WTP studies for rice milled at 11% (a medium-level) which could be an acceptable compromise on milling level while still obtaining some increased zinc intake. Additionally, evaluating how consumer WTP changes when the provider, information framing, and information medium is altered is of interest. Finally, conducting similar research in peri-urban/urban areas would be useful in scaling up awareness campaigns to reach these consumers as they likely have greater access to nutritious diets and/or income for supplementation and fortified food than the rural population focused on in this study.

Looking forward, given the results of this study, the best method to increase Bangladeshi consumer’s dietary zinc intake is through a combined effort of zinc biofortified low-milled rice

group that receives both zinc biofortification and low milling information, something our experiment did not include. We identify this as something future studies should explore.

[11] The exact logistics and cost details surrounding this strategy, though important, are outside the scope of this research.

and fortified rice[12]. Fortified rice can be high-milled as micronutrients are added post-milling. Though this substantially increases processing costs (Andrade et al., 2021). Given the cost considerations, sustainability, and the fact that rice processing is currently not fully centralized/automated, biofortified zinc rice is advantageous over fortified rice. Although the opposite remains true regarding consumer preference for high-milled rice. Therefore, this study's findings may prove useful as a benchmark for consumer acceptance of zinc-dense rice and help identify the trade-offs and complementarities between different approaches, including fortification and biofortification.

[12] See Appendix A.2 for further discussion on fortified rice.

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APPENDIX

A.1 Biofortified Zinc Rice Production Costs

As one evaluates the full viability of the zinc biofortified rice, it is imperative to consider the production costs in light of potential consumer WTP for the product. Therefore, we share the below details regarding the cost of cultivation for the crop. There are no additional costs to farmers for producing zinc biofortified rice compared to non-biofortified rice. For example, the price of zinc biofortified seed is not different than the seed price of commonly cultivated non-biofortified improved varieties (HarvestPlus, 2021; BRRI, forthcoming). A review of zinc biofortified rice varieties in India (which shares common rice growing conditions and practices with Bangladesh) indicates that zinc biofortified rice require no additional expenditures on external inputs or agronomic practices (Rao et al. 2020). This is also confirmed for Bangladesh by a study conducted by the Bangladesh Rice Research Institute (forthcoming). Therefore, in theory, there is no additional production cost to the farmer that must be recovered when selling the zinc biofortified rice in the market. Further, through targeted breeding, biofortified rice varieties promoted have no yield disadvantage to non-biofortified varieties (Andersson et al., 2017; Rao et al., 2020).

A.2 Additional Forms of Dietary Zinc Intake

Aside from zinc biofortified rice, zinc content in other commonly consumed foods in Bangladesh. is as follow: fortified rice (> 35 μg/g) though not yet scaled-up for population-level consumption, lentils (11.8 μg/g), main species of fish, shrimp, and prawns (6.0 μg/g – 47.0 μg/g), and eggs (12.4 μg/g) (Andrade et al., 2021; USDA, 2019A; Bogard et al., 2015; USDA, 2019B). In terms of yearly per-capita consumption of these foods in Bangladesh, as expected, rice is by far the most heavily consumed of these food products with an individual, on average, consuming 182 kgs/year (FAO, 2022). Fish and prawns are the main animal-source food in the Bangladesh (Belton et al., 2014) contributing approximately 18.1 kgs per-capita per year consumed (rural: 16.7 kgs/yr, urban: 21.86 kgs/year). Further, in thinking towards the future, it has been found that although fish consumption per-capita has increased in Bangladesh in recent years due to the expansion of aquaculture, fish farmed via aquaculture contain less micronutrient content than indigenous fish specifies (Belton et al., 2014). The average pulse intake as a whole, not only limited to lentils, is estimated to be 3.9 kgs/per-capita/year (Heady and Hoddinott, 2016). While pulses contain high zinc content, they contain phytates which bind zinc and inhibits its absorption by the body (Institute of Medicine, Food and Nutrition Board, 2011; Sandstrom, 1997; and Wise, 1995). Finally, egg consumption in Bangladesh is extremely low with FAO reporting the 2019 average per-capita yearly consumption of 2.78 kgs (FAO, 2019).

Of the aforementioned dietary zinc intake methods, the one with the highest zinc content is zinc fortified rice so we will delve into a short discussion of this intervention. There are major efforts underway to explore the efficacy and current food environment to fortify rice in Bangladesh (FFI, 2021). Since 2013, chemically fortified rice, where micronutrients are sprayed onto the grain, has been distributed through the government's social safety net program targeted to the poor at no additional cost or at significantly subsidized rates (Andrade et al., 2021). As fortified rice can contain high levels of micronutrients and can be sold in the preferred high-milled form, it is an advantageous intervention given the results of this study. A main challenge, however, is the sustainability of this approach given that it costs 4 BDT/kg to chemically fortify rice grains (Andrade et al., 2021). If these costs are passed on to consumers, it can increase the cost of this staple food for poor people who need micronutrients the most.

However, Chowdhury et al. (2021) find a positive WTP for fortified rice in the presence of aspirational product messaging. Further, to our knowledge, no acceptability tests (e.g., organoleptic evaluation, home cooking experience, etc.) of the chemically fortified rice has been conducted.

A.3 Data and Descriptives

Based on treatment effects from previous WTP studies (Birol et al. 2015; Zossou et al. 2022), an average treatment effect of 6%with an effect size/standard deviation ratio of 1/3, common in similar WTP studies was used. Along with 80% power of a Type II error and a 5% significance level of a Type I error, the required sample size for each study group was 73 respondents. The study was designed to be able to measure each treatment effect pooled across districts and within each district, though the decision was made during analysis to present only the pooled data as there were minimal differences in observations between districts.

Prior to selection of the 576 respondents, field sites were visited a week before to conduct a listing of all households in the block administrative level that purchased rice from the market and planned to do so within the following two weeks. Local Ministry of Agriculture's Sub-Assistant Agriculture Officer (SAAO) helped to develop this study's sampling frame. Households in the sampling frame were selected at random and were then called two days prior to the study to ensure they were still available to participate and anticipated purchasing rice for their household in the week to come. The main rice purchaser from each household that confirmed their intent to purchase rice and interest in the study were invited to a nearest community hall.

Due to the consumer acceptance portion of the study involving the evaluation of rice grain through cooked rice taste tests (not covered in this paper), participants were brought together for central-location testing (CLT) at their nearest upazila-level (the administrative unit below districts) community hall. Within each district, each upazila, and each block, respondents were randomly assigned to the control and two treatment groups.

Enumerator training was conducted in Dhaka and Gazipur, Bangladesh from 22-28 October, 2018, including one day for pretest of the instrument. In total, 16 enumerators were trained and 12 were selected to serve as enumerators during data collection based on performance during the pre-test and a short, written exam about topics on which they had been trained. The four trained enumerators not selected served as support staff in cooking and serving rice for the consumer acceptance portion of the study and were available as backup enumerators.

Due to logistics constraints, the enumerator team was unable to go to the field immediately following training. Therefore, a one-day refresher training was conducted prior to field data collection which began December 8-13, 2018 in Dinajpur district. Due to civil unrest that began earlier than expected prior to the national election, the study was paused following data collection in Dinajpur. Once deemed safe for enumerators to resume data collection, the second district of Satkhira was visited during March 20-25, 2019. Among the 16 originally trained enumerators, 12 were still available to participate in data collection in Satkhira. Again, a refresher training was conducted prior to going to the field due to the time lag since the last data collection took place in December.

Upon return from the field, data was entered by Agricultural Economics officers at BRRI and 20% of questionnaires were spot-checked for data entry quality. This process was completed in June 2019. Table A1 includes a list of variables used in the analysis.

Table A1: Variable list for models

Variable name	Description
Zincinfo	1 if the respondent received information on zinc biofortified rice; 0 otherwise
Millinfo	1 if the respondent received information on the nutritional impact of high milling on rice; 0 otherwise
under5	Number of children in the household that are 5 years of age or younger
Hhsize	Number of individuals in the respondent's household
Dinajpur	1 if the respondent was from the Dinajpur district
Education	Number of years of formal education the respondent had obtained
Farm	1 if the respondent's main occupation is farming (either their own property) or as a farm-laborer on someone else's farm; 0 otherwise
Age	Age of respondent in years
Female	1 if the respondent is female; 0 otherwise
Percapincome	Monthly per-capita income for the household (in 1,000 BDT)
Percapconsump	Yearly per-capita rice consumption for the household (in 10 kgs)
Purchfreq	1 if the respondent purchases rice daily or multiple times per week for household consumption; 2 if the respondent purchases rice weekly or twice a month for household consumption; 3 if the respondent purchases rice monthly or less often for household consumption
Morning	1 if the survey was conducted in the morning; 0 otherwise
Hungry	1 if the respondent was hungry at the time the survey was conducted; 0 otherwise
Awarehzr	1 if the respondent was aware of biofortified, high zinc rice varieties prior to participating in the survey; 0 otherwise

The full study, including the consumer acceptance sensory evaluation portion, took respondents approximately 2 hours to complete with the WTP portion and structured socio-economic survey administered last. All questions were asked in the Bangla language and data was collected via paper-based surveys due to budgetary limitations.

A.4 Information Scripts

Treatment Group 1: Zinc Biofortified Rice Information

Hi, did you know that 1 in every 3 Bangladeshis suffer from not enough zinc intake. Zinc is an important nutrient for the body for proper brain development and physical growth making sure that children become more intelligent and are not stunted. Zinc is also important for building up your body’s immunity decreasing the risk of diarrheal disease and pneumonia, which are the two most common diseases in children. Therefore, zinc is especially important for children and pregnant women. Did you know that there is rice available, here in Bangladesh, that has higher zinc content than regular rice varieties? These high zinc rice grains can provide up to 70% of your daily zinc requirements. That's why to ensure you and your family get enough zinc in your diet for your body's needs, eating high zinc rice is the way to go! Among the samples presented, rice sample "ORANGE" is the high zinc variety.

Treatment Group 2: Low-Milling Information

Most people like shiny, white rice because it looks better. But the fact is that the shinier and whiter it is, the less nutritious it is. When it is polished greatly to give that appearance, the nutrients go away. Although the dull rice does not look as nice, it has more nutrients. Purchasing and consuming white, highly polished rice may satisfy you but less-polished rice will make you healthier. Among the samples presented, rice samples "GREEN" and "ORANGE" are less polished, more nutritious varieties.

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CHAPTER 2. FARMER ASPIRATIONS AND WILLINGNESS-TO-PAY FOR BIOFORTIFIED BEAN SEED: A FIELD EXPERIMENT IN RURAL ZIMBABWE

1. Introduction

Aspirations, the strong desire or hope of achieving something in the future, is gaining traction in the development economics literature as one potential way to explain individuals' choices and actions, especially for medium- and long-term investments. High-aspiring individuals have been found to be more forward-looking and entrepreneurial and are more likely to save, take up new technologies with potentially large payoffs, and invest in their children's education (Janzen et al., 2017; Kosec & Khan, 2016; Dalton et al., 2015; Bernard et al., 2014; Villacis et al., 2022). Conversely, low aspirations have been associated with worse health outcomes (Echavarri & Husillos, 2016).

We explore farmer aspirations in the context of willingness-to-pay (WTP) for biofortified bean seed. Biofortification is the conventional breeding of staple food crops to improve their nutritional content, without compromising the traits that generate economic benefits (e.g., resistance to pests, increased yield, and better quality) (Bouis and Saltzman, 2017). Biofortification is specifically targeted to rural populations who are micronutrient deficient and lack access or income to address this deficiency by other means such as consuming a diverse diet, supplementation, or consumption of fortified foods (Bouis and Saltzman, 2017). The majority of developing countries' rural populations' main source of employment is agriculture and most rural farmers reserve a portion of their harvest for household consumption. Therefore, biofortification's impact pathway is reliant upon rural farmers growing and consuming biofortified seed varieties. The realized health benefits from consuming biofortified crops, however, are not immediate and are considered a medium-term investment. Therefore, a key question of interest is, all else equal, what motivates farmers to purchase and grow biofortified crop seed instead of non-biofortified seed.

In this study, we explore this research question via an experimental approach with Zimbabwean farmers and investigate two potential mechanisms that we believe are linked. In the first mechanism, we explore the influence of farmer aspirations on their willingness-to-pay (WTP) for biofortified bean seed. Because the benefits of growing and consuming biofortified crops is a medium-term investment, we hypothesize that farmers who have higher aspirations for the future (specifically regarding agricultural revenue as well as family education and health) will pay more for biofortified seed. The second mechanism we evaluate is the impact of biofortified crop information on farmer demand for biofortified crops. As the health benefits are linked to consumption of biofortified crops, we information is focused on consumption traits. We then link these two mechanisms together by exploring if, and to what degree, differences exist between how high aspiring and low aspiring farmers respond to consumption information, as evidenced by their WTP. Given previous literature, we hypothesize that farmers with higher aspirations will be more responsive to the information and therefore, have a higher willingness to pay for biofortified seed than farmers with lower aspirations. We explore these mechanisms for bean farmers in Zimbabwe.

We make several contributions to the literature. First, we contribute to the growing body of literature on the economics of aspirations by examining the impact of farmers' aspirations on their WTP for a seed with a benefit realized in the medium-term. To our knowledge, only one study (Martey et al., 2023) has looked at the intersection of aspirations, information, and WTP. Martey et al. (2023) examined the role of farmer's aspiration on their WTP for a soil water monitoring tool in Ghana. They do not find a significant association between irrigation information access and WTP for farmers with a high aspirations index score and therefore, suggest that high aspirations may not necessarily translate to adoption of their study's soil monitoring tools. Aside from aspirations, the WTP literature includes studies that examined variables typically thought of as innate unobservable characteristics of individuals that influence preference and behavior. For example, WTP studies have incorporated personality measures (for consumers see Grebitus et al., 2013; Lin et al., 2019; Ufer et al., 2019; for producers see Morgan and Farris, 2021), trust (DeLong and Grebitus, 2018) and risk aversion assessments (Armah and Schwab, 2019; Channa et al., 2021). We bring these two bodies of literature together in this study. As farmer aspirations are an unobservable trait, we identify the observable characteristics that are significantly different between high and low aspiring farmers, which seed dealers and extension agents can use for targeting high aspiring farmers.[13]

Second, we disentangle the impact of varying information levels on farmer WTP. Information shared can influence consumer and producer WTP, where the information can range from limited to extensive. Examples of minimal information that can influence WTP are product labels (Demont and Ndour, 2015) while more extensive information has also been shown to influence WTP including reading, watching a video, or listening to an audio clip (Channa et al., 2019; Herrington et al., 2023). Therefore, to assess the level of information needed to impact farmer WTP for biofortified bean seed we separate out three levels of information: labeling information, information on micronutrient deficiency and the nutrition of biofortified seeds, and cooking quality and taste information of the biofortified seeds, assessed through three bidding rounds. In doing so, we measure how WTP changes when each new piece of information is shared with farmers, the results of which are useful to seed companies that sell biofortified bean

[13] We delve into this literature in the next section.

seeds as well as agricultural extension agents and seed delivery partners who promote the cropping of biofortified beans.

Our third contribution is that we measure producer acceptance and demand for a new seed variety with proper credence attribute labeling. While there have been many studies of consumer acceptance and WTP for food products with nutrition (e.g., De Groot et al., 2011; Herrington et al., 2023), value-added (e.g., Michel et al., 2011), and food safety enhancement traits (e.g., Tonsor et al., 2009; Ortega et al., 2011; Walke et al., 2014), such studies with a focus on producer WTP are rare. The few studies that have assessed farmer WTP for new seed attributes, have primarily focused on agronomic or seed quality traits (Mastenbroek et al., 2021; Maredia et al., 2019; Morgan et al., 2020; Win et al., 2022; Maredia and Bartle, 2022), and not consumption characteristics, which are the key seed traits of interest in this study. We emphasize consumption traits because most farmers in Zimbabwe are smallholders who often keep a portion of their harvest for own consumption, and therefore likely assess both agronomic and consumption traits when making seed purchase decisions.

The remainder of this paper is organized as follows. In Section 2, we provide a review of aspirations economic literature, a background on micronutrient deficiency, the importance of beans to the Zimbabwean agricultural sector, and the biofortification of beans in Zimbabwe. In Section 3, we detail our methodology and describe the study design, hypotheses, and the empirical strategy. We present descriptive and econometric results for the impact of information on farmer WTP by round, bean variety, and level of aspiration in Section 4 as well as compare differences in observable characteristics for high versus low aspiring farmers. Finally, Section 5 concludes and discusses the implications of the study findings.

2. Background

We first provide a review of the current literature on the links between aspirations and economic development to better establish a foundational understanding of what types of studies have utilized aspirations to assess specific decision-making regarding the uptake of actions and/or interventions. From there, we expand the literature by assessing the linkage of farmers' aspirations for the future and their WTP for biofortified beans. To best understand why we evaluate the linkage of aspirations to the of purchasing biofortified beans, we provide context regarding high micronutrient deficiency in Zimbabwe which biofortified beans combat. We also provide details regarding breeding, delivery, attribute information, and the timeline for nutritional impacts of the biofortified beans.

2.1 A Review of Aspirations' Impact on Future-Oriented Behavior

Recent studies that explored the link between aspirations and investment decisions found that aspirations may partially explain investment decisions (Genicot and Ray, 2017; Fruttero et al. 2021; Janzen et al., 2017; Bloem, 2021; Villacis et al., 2022). Exploring this connection between aspirations and investment could be a potential mechanism to explain low uptake of potentially high payoff investments or opportunities. Bernard et al. (2014) conducted a randomized controlled trial (RCT) in rural Ethiopia where one group of individuals was shown a documentary about people of similar communities who had succeeded in agriculture or small business while the other group watched a placebo video. Aspirations were measured before the videos and then six months after the video viewing. The researchers found evidence of aspiration's treatment effect on savings and credit behavior, children's school enrollment, and investment in children's schooling, which suggests that changes in aspirations can translate into changes in forward-looking behavior. While Bernard et al. (2014) took an experimental approach, most other aspirations studies have used observational data. In various contexts, studies have found that aspirations are important in influencing future-oriented behavior including higher investments in school enrollment, nutrition, occupation type, and employment income (Macours and Vakis, 2009; Beaman et al., 2012; Knight and Gunatilaka, 2012; Bernard and Taffesse, 2014). Finally, specific to agriculture, Knapp et al. (2022) found that the behavioral factor of farmer aspirations, measured directly on a 10-point Likert scale, is context-specific in explaining Swiss farmers' agricultural decision-making. The authors find that aspirations are positive and significant in predicting the uptake of preventative pest management strategies and the uptake of hail insurance but not in the case of entrepreneurial activities of processing and direct marketing of goods.

It is evident from this review that an individual's aspirations for the future can partially explain decisions regarding the future through various actions and/or uptake of interventions. We use this research as a basis for the motivation of our research question – do high aspiring farmers have a higher WTP for biofortified bean seeds, whose benefit is not immediate. We extend the literature by bringing together the behavioral economics aspirations research with WTP methodology to potentially explain an individual's WTP for specific product attributes. The methodology used in several of these research studies lay the groundwork for the approach used in this study to assess farmer aspirations.

2.2 Micronutrient Deficiency in Zimbabwe

One in two individuals in Zimbabwe is at risk for inadequate zinc intake while 72% of children under five and 61% of women of reproductive age are iron deficient (Wessells et al. 2012; Zimbabwe Food and Nutrition Council, 2012). Iron deficiency can lead to mental development impairment, increased weakness and fatigue, and increase the risk of women dying during childbirth while zinc deficiency can impair proper physical growth which can lead to stunting, impair cognitive development, and weaken the immune system (Black et al., 2013; Wessells et al., 2012). These health consequences are costly; the estimated economic cost due to vitamin and mineral deficiencies in Zimbabwe is approximately US$24 million annually (World Bank, 2013). Increased micronutrient and mineral intake can best be attained by a diet that is both calorie and nutritionally rich. However, as 49% of Zimbabweans live in extreme poverty, it is difficult for many to afford such a diet (WFP, 2022).

2.3 Importance of Common Beans in Zimbabwe's Agricultural Sector

Agriculture serves as a backbone of the Zimbabwean economy, constituting the primary livelihood for 70% of the population, 23% of formal employment, and 10% of national GDP (ZimStat, 2022; WFP, 2021). Within agriculture, beans are among the primary crops grown in the country and serve as a key source of nutrition, income, and food security (Katungi et al., 2021). In 2021, approximately 34,000 hectares were planted to beans, which led to total production of 22,000 metric tons with all production staying in-country as food supply (FAOSTAT, 2023).

2.4 Zinc and Iron Enriched Biofortified Beans

Because most Zimbabwean smallholder bean farmers consume at least a portion of their own production (Katungi et al., 2021), biofortified beans enriched in iron and zinc offer one intervention to address these nutritional deficiencies. The first zinc and iron biofortified bean seed variety was released in the country in 2015. Two biofortified bean varieties, both classified as sugar beans, have been developed through a partnership between the CGIAR's HarvestPlus Program and CIAT (the International Center for Tropical Agriculture), the United Nation's Food and Agriculture Organization (FAO), UK Aid, and the Zimbabwe Ministry of Agriculture

(HarvestPlus, 2020). To date, however, only one of the bean varieties, NUA45, has been heavily promoted and made available for sale by seed companies. Though NUA45 has been available since 2015, Ministry of Agriculture estimates suggest that approximately 13% of all bean area is planted to biofortified beans (ZimStat, 2022), meaning many individuals likely do not know about the variety or lack access to the seed. Furthermore, as zinc and iron are invisible crop traits, the only way for farmers to know about the nutrition benefits of biofortified seed is through information communication. Yet, the main seed company selling this variety does not include any product labeling on its seed packs that indicates its nutritional benefits, leaving farmers unaware of these advantages.

NUA45 was primarily bred for increased iron intake and has 75 milligrams of iron per 1kg (Talukder et al., 2010), whereas standard beans typically have around 50 milligrams of iron per 1kg (Andersson, 2017). When eaten regularly, biofortified beans can provide up to 80 percent of daily iron needs for women of reproductive age and children (HarvestPlus, 2020). Since iron and zinc are co-localized in the bean grain, the zinc content increases with iron, such that NUA45 contains 41 mg/kg of zinc compared to an average zinc content of 35 mg/kg in non-biofortified beans (Talukder et al., 2010). Further, NUA45 is fast cooking and swells to twice its size when cooked, both of which are preferred traits by consumers (Nchanji et al., 2022). Agronomically, NUA45 is a large-seeded, mottled bush bean (40g/100 seeds), is early maturing (85 days), yields up to 3 tons/hectare, and is tolerant to common bean diseases in Zimbabwe such as bean rust angular leaf spot and bacterial blight (HarvestPlus, 2020; Chirwa and Mankhwala, 2021). These agronomic traits are on-par with Gloria, a popular seed type which is also a large-seeded bush bean (44g/100 seeds), early maturing (93 days), yields up to 3 tons/hectare, and has good tolerance to bean rust and bacterial blight (National Tested Seeds, 2023).

The health benefits of consuming biofortified beans are not realized immediately and can be viewed as a medium-term investment. In Rwanda, iron-depleted female university students, aged 18-27, experienced a significant increase in iron status after consuming iron beans daily for 4-5 months (Haas et al., 2016). In Mexico, children aged 5-12 who ate iron enriched beans for six months had significant improvements in their iron status (Finkelstein et al., 2019). While neither of these studies used the same bean variety as this experiment, the iron and zinc levels are similar. In the context of this study, the pay-off horizon is medium-term, approximately one year, as farmers will first have to plant and then harvest the beans, and then eat a considerable portion on a regular basis before obtaining health benefits. This medium-term benefit horizon motivates our interest in segmenting the farmer population into those with low versus high aspirations for the future regarding agricultural income, family education, and health. This will allow us to assess if these aspirations impact how they incorporate information received into their WTP bids.

3. Methodology

3.1 Methods

People draw upon mental models to interpret information and make decisions (Jones et al., 2011), though these mental models can also lead to cognitive biases and the neglect of relevant information and underinvestment (Hoff and Stiglitz, 2010; Gilovich et al., 2002; B´enabou, 2012; Hanna et al., 2012). Bernard et al. (2014) note that aspiration is one such mental model which should be evaluated in understanding people's take-up of opportunities, proxied in this study as WTP. Further, while not aspirations, Grebitus et al. (2013) find that personality, another innate individual characteristic, influences preference construction, proxied by WTP, with different personality types having different susceptibilities to anchors, cues, and information.

Our experiment follows a within-subject design with three rounds of information. The study was comprised of 262 respondents, from six provinces in Zimbabwe.[14] We utilize the incentive-compatible, non-hypothetical Becker-DeGroot-Marschark (BDM) auction-like mechanism, often used in experimental economics to measure WTP (Becker, DeGroot, & Marschak, 1964). The main benefit of using the BDM mechanism is that it allows for a quasi-market scenario that can be carried out with only one respondent present. We elected to use this method for eliciting WTP as this experiment was part of a larger farmer survey that took place in or near each farmer's house where only the enumerator and respondent were present. As with any method, BDM does have drawbacks. The main drawback of BDM is that it can be difficult to explain and for respondents to understand compared to other experimental auctions (Asioli et al., 2020; Cole et al., 2020). Consequently, we utilized a practice round with matchboxes, a known item, to ensure farmers understood the procedure before carrying out the experiment.

In the BDM mechanism, respondents submit a bid that is compared against a randomly drawn price from an *ex-ante* established market price distribution, which is based on current average prices for the good(s) being evaluated. If the respondent's bid is greater than or equal to the randomly drawn market price, they pay the randomly drawn price and receive the good; otherwise, no transaction occurs. In the case of individuals bidding on multiple goods and/or in multiple rounds, one of the goods and one of the bidding rounds are selected at random to be binding such that only one good's bid in a specific round is compared against the randomly drawn market price. In this mechanism, the respondent's true WTP for a unit of the good is defined as the price that induces a utility indifference between winning and not winning the unit of the good. Therefore, rational behavior under the BDM mechanism is for the respondent to

[14] Sampling details for this study are outlined in Appendix A.3.

place a bid equal to their true WTP (Lusk and Shogren, 2007). For this study, the difference in bids between different bean seed packs reveals the premium, or discount, due to the different bean seed attributes as perceived by the farmer.

3.2 Aspirations Measurement

To measure aspirations, we follow the procedure utilized by Bernard and Taffesse (2014) while incorporating updated methodology from Kosec et al. (2022) by asking farmers about current levels of certain outcomes and their associated aspired levels of such outcomes over their lifetime. We measure farmer aspirations across five dimensions: gross agricultural revenue, agricultural assets, social status in agriculture, family education split between men (boys) and women (girls), and physical health and well-being of children (split between boys and girls) in the household. The last dimension, physical health and well-being is a new dimension we added to the aspiration's measurement, given the nutrition consumption attributes of the biofortified beans included in this study.[15] As individuals may have different views on the relative importance of the five dimensions, they are asked to distribute a total of 100 points across the five categories, according to the dimension's importance to them. The share of points placed on a dimension serves as its weight for that individual.

However, to calculate the index across all five dimensions, the individual's aspiration in each dimension can be standardized by subtracting the sample mean for that dimension and then dividing the difference by the standard deviation. Then, the weighted sum is computed by using the individual's weights outlined in Equation 1 below (Bernard and Taffesse, 2014; Kosec et al., 2022).

$$A_i = \sum_{n=1}^{5} \left(\frac{a_n^i - \mu_n}{\sigma_n} \right) w_n^i \qquad (1)$$

[15] Specific questions asked are outlined in Appendix A.1.

where a_n^i is the aspiration for dimension *n* for individual *i* as detailed above. μ_n and σ_n represent the sample mean and standard deviation of a_n^i, and w_n^i is the weight individual i places on dimension n. The resultant index is then standardized so it is normally distributed with mean 0 and variance of 1 across the sample of individuals in the experiment via equation 2 below.

$$\text{Standardized } A_i = \frac{A_i - \mu_i}{\sigma_i} \qquad (2)$$

Following the standardized aspirations index score for each farmer, a binary variable is created to represent high aspiring individuals. Farmers classified as 'high aspiring' have a standardized score at or above the median standardized score of all farmers in this experiment.

3.3 Study and Experimental Design

To assess how information may change farmer preferences and valuation for bean seed and the potential differential effect of information on bean seed valuation by low- and high-aspiring farmers, farmers formulated bids for bean seed three times. In each of the three rounds, the enumerator shared new information with the farmers and after each round, farmers were asked what price they would be willing to pay for each of the three, 2kg bean seed packs. Farmers were informed they could keep their WTP the same as in the last round or update it. Given three rounds of bidding for three bean types, farmers submitted nine bids in total. For transparency, enumerators recorded respondent bids in the CAPI (Computer Assisted Personal Interviews) program and physically filled out a bid sheet for each round/product as the farmer gave each bid.

In the first round of bidding, bids were based solely on the information available from the 2kg seed packs and any other visible attribute (e.g., seed color). We utilize 2kg seed packs as they are the smallest and most common size available in the market for purchase. Two of the three seed packs are NUA45, the biofortified high iron and zinc seed variety. One of the NUA45 seed packs is labeled "Iron and Zinc enriched" while the other one has no such label, reflective of how the seed pack is currently offered in the market. The third type of seed evaluated in this study was Gloria, the most popular non-biofortified bean seed variety. Other than the bean seed name, and the "iron and zinc enriched" label for one of the NUA45 products, all other information on the bags was the same. The type of information included on the seed packs and the visible traits of the seed are described in Table 2.1. A picture of seed packs used in the experiment is shown in Appendix A.2.

Table 2.1: Information on bean seed packs

	Beans Seed Type		
Information type	*Product 1*	*Product 2*	*Product 3*
Variety name	Gloria	NUA45	NUA45
Company name	ARDA	ARDA	ARDA
Size	2kg	2kg	2kg
Seed treated with a chemical?	No	No	No
Color of the seed	Cream	Purple Mottled	Purple Mottled
Seed type	Certified	Certified	Certified
Additional label?	No	No	Iron and Zinc Enriched

Information shared by enumerators in each round is provided in Table 2.2. All enumerators read from the same script to ensure that information remained consistent; the script was translated in Shona and Ndebele, the two most common local languages spoken throughout the country (see Appendix A.2 in the appendix for full English scripts).

Table 2.2: Study design - information provided in each bidding round

	Information
Round 1	*Information on seed packs described in Table 1 above*
Round 2	*Script read by enumerator with following information:* - Prevalence of iron and zinc deficiency in Zimbabwe - Health impacts of those deficiencies - Consuming iron and zinc enriched beans can help meet daily iron and zinc needs
Round 3	*Script read by enumerator with following information about NUA45:* - cooking time, cooking quality (size), and taste

Prior to conducting the experiment, enumerators explained the BDM procedure to farmers and conducted a non-hypothetical practice round. The practice round was comprised of three matchboxes, each of a different brand, a common product in rural Zimbabwe with known market prices to familiarize the farmers with the BDM procedure. Specifically, farmers were told to bid for each product independently (i.e., not to spread their available purchasing power across multiple products because at the end they may have the opportunity to purchase only one product and in one bidding round).

The *ex-ante* established price distribution used in the experiment for bean seed was $0-14 USD[16], in increments of $1 USD.[17] The price distribution was double the current average market price of bean seed, which was $7.00/2kg pack. This price distribution was not revealed to respondents, though respondents were told to think of the bean seed price currently found in the market. No endowment or participation fee was given to farmers, so their bids were reliant upon the amount of their own money they had at the time of the survey.[18] As such, 16% of farmers had the opportunity to purchase bean seed but refused to do so. We control for these farmers in the analyses.

At the conclusion of the bidding rounds, respondents then drew the binding round, product, and market price. The binding market price was compared against the farmer's bid for the binding round and product. If the farmer's bid for the binding round and product was greater than or equal to the randomly drawn market price, the farmer paid the market price and received the 2kg seed of the binding product.

3.4 Research Hypotheses

There are three overarching hypotheses for this study. The first null hypothesis is that the

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[16] Zimbabwe operates with two currencies– the US dollar and the local Zimbabwean dollar, officially the Real Time Gross Settlement (RTGS) dollar, which was reintroduced in 2019. Due to inflation in the RTGS since its reintroduction, most individuals prefer to use USD. As such, we used USD as the currency in this study.
[17] Though seed prices in the market are not always set in whole dollar increments, increments of $1 were used in this study due to logistical currency challenges (i.e., coin shortages).
[18] Prior to the survey, supervisors informed the village leaders that as part of the survey there may be an opportunity for farmers to purchase real bean seeds so therefore, to alert farmers to have money available.

average WTP for each bean seed type is not statistically different from one another. We conduct this analysis for each of the three rounds to determine whether the average WTP is significantly different, and if so, the relative premium (discount) for each bean type. In round 1, the difference in WTP between Gloria and NUA45 with no nutrition label will signify if farmers have a bean seed color preference. The difference in WTP between the bean types in rounds 2 and in round 3 will determine the cumulative effect of the information shared on total WTP across the bean seed types. In round 1, we have no expectation for the alternative hypothesis for the average WTP comparison between Gloria and NUA45 without the nutrition label as we are not aware of any strong color preference. However, given the additional information provided via the nutrition label, the alternative hypothesis for the two NUA45 products is that the WTP for NUA45 without the label will be less than or equal to the WTP for NUA45 with the label. In round 2, the information provided is related to NUA45 with the nutrition label, so we suspect average WTP for NUA45 with the label will be greater than or equal to WTP for NUA45 without the label. Finally, in round 3, the information provided is about NUA45 in general so we hypothesize that average WTP for NUA45 without the nutrition label will be greater than or equal to Gloria.

$$H_0^1: WTP_{Gloria} = WTP_{NUA45\ no\ label} = WTP_{NUA45\ with\ label}$$

$H_A^1: WTP_{WTP_{Gloria}} \neq WTP_{NUA45\ no\ label} \leq WTP_{NUA45\ with\ label}$ for round =1

$H_A^1: WTP_{WTP_{Gloria}} \neq WTP_{NUA45\ no\ label} \leq WTP_{NUA45\ with\ label}$ for round =2

$H_A^1: WTP_{WTP_{Gloria}} \leq WTP_{NUA45\ no\ label} \leq WTP_{NUA45\ with\ label}$ for round =3

Our second null hypothesis is that sharing information (via label, nutrition information, or consumption information) has no effect on farmers' WTP. However, past studies have shown that information can impact WTP (Demont and Ndour, 2015; Birol et al., 2015; Herrington et al., 2022) so our alternative hypothesis is that information does change farmers' WTP. Specifically, we assess the incremental impact of round 2 information on farmer WTP for each bean product compared to their round 1 WTP, and similarly for round 3 versus 2 WTP. We also assess the cumulative impact of all information shared by comparing average WTP from round 3 to round 1 for each bean type. As the impact of information could positively or negatively impact WTP by bean type, the alternative hypothesis is two-sided.

$$H_0^2: WTP_{Pre-Info} = WTP_{Post-Info}$$

$$H_A^2: WTP_{Pre-Info} \neq WTP_{Post-Info}$$

Our third hypothesis investigates the impact of farmer aspirations on WTP. Specifically, our null hypothesis is that there is no differential effect of information on WTP by farmer aspirations level. The corresponding alternative hypothesis is that there is a statistically significant WTP effect of information for high aspiring compared to low aspiring individuals. This hypothesis is formed based on past studies that have found that respondent personality, a similar unobservable construct to aspirations, does impact producer and consumer WTP (Grebitus et al., 2013; Canavari et al., 2019; Lin et al., 2019; Ufer et al., 2019; Morgan and Farris, 2021). Similar to the finding of Grebitus et al. (2013), in that personality influences preference construction with different personality types having different susceptibilities to anchors, cues, and information, we investigate this in the context of aspirations. We test this hypothesis by including a binary variable with 1=high aspiring farmer and interact that with both rounds and bean types.

$$H_0^3: WTP_{Impact\ of\ Info, High-aspiring} = WTP_{Impact\ of\ Info, Low-aspiring}$$

$$H_A^3: WTP_{Impact\ of\ Info, High-aspiring} \geq WTP_{Impact\ of\ Info, Low-aspiring}$$

3.5 Empirical Strategy

Given that individuals submit bids on multiple seeds in multiple rounds, we estimate the impact of information and aspirations level on farmers' WTP via fixed effects Ordinary Least Squares estimator.[19] We cluster our standard errors at the household level to account for any within-farmer correlation in error terms as each farmer submitted nine bids, one for each bean seed type in three rounds of bidding.

To determine if any differences exist in farmer WTP for the three different bean seed types, we estimate equation 3 by rounds. Specifically, in round 1 we assess the impact of color difference on WTP by examining the difference in Gloria and NUA45 with no label. To assess the impact of the label in round 1, we estimate the difference in WTP for NUA45 with the nutrition label against NUA45 without the nutrition label. In round 2 and round 3, we examine the impact of information presented in each round on the spread between the average WTP for each bean seed type. In equation 4, we then incorporate farmer aspirations as an explanatory variable, defined as high aspirations, HA, (0/1), to assess if high aspiring farmers bid differently for the various bean seed types compared to low aspiring farmers.

$$Model\ 1: Bid_{ijr} = \alpha + \beta_j P_j + \boldsymbol{\eta F_i} + u_{ijr} \qquad \textit{for each r (round) =1, 2, 3} \qquad (3)$$

$$Model\ 2: Bid_{ijr} = \alpha + \beta_j P_j + \boldsymbol{\delta}(P_j\ x\ HA_i) + \boldsymbol{\eta F_i} + u_{ijr} \qquad \textit{for each r (round) =1, 2, 3} \qquad (4)$$

where Bid_{ijr} is the WTP bid for farmer *i* for bean seed type *j* for round *r*. P_j is a categorical variable for the bean seed type (=0 NUA45 with no nutrition label, =1 for Gloria, the non-biofortified bean, and =2 for NUA45 with the nutrition label). We use NUA45 without the nutrition label as our base bean for ease of comparison to Gloria for any color premium/discount, and to NUA45 with the label for the label premium/discount. The $\boldsymbol{F_i}$ represents farmer-level fixed effects. Finally, u_{ij} is the idiosyncratic error term.

We test for differential effects of the different rounds of information by aspirations level

[19] Given that less than 5% of WTP bids were zero, we use OLS over Tobit estimators (Canavari et al., 2019).

by utilizing equations 5 and 6 below, which are estimated separately for each bean type.

$$Model\ 3: Bid_{ijr} = \alpha + \beta_r R_r + \boldsymbol{\eta F_i} + u_{ijr}$$

for each j=Gloria, NUA45 no label, NUA45 with label (5)

$$Model\ 4: Bid_{ijr} = \alpha + \beta_r R_r + \boldsymbol{\delta}(R_r\ x\ HA_i) + \boldsymbol{\eta F_i} + u_{ijr}$$

for each j=Gloria, NUA45 no label, NUA45 with label (6)

where Bid_{ijr} is the WTP bid for farmer *i* for bean seed type *j* for round, *r*. Equations 5 and 6 are the same as equations 3 and 4 above with the substitution of $\beta_r R_r$ for $\beta_j P_j$ where R_r is a categorical variable for bidding round (=0 for round 1, =1, for round 2, =2 for round 3). Round 1 serves as the base group for comparison. For each bean variety, we assess the impact of nutrition deficiency and biofortified bean nutrition information provided in round 2 compared to round 1 and cumulative impact of nutrition and consumption information by comparing round 3 to round 1. To assess the incremental impact of consumption attribute information, we carry out post-estimation tests comparing average WTP between round 3 and round 2.

3.6 Data

In this sample of 262 farmers, 77% of farmers were their household's head, 42% were female, on average they were 51 years old, the majority had completed secondary school, and on average, their household size was five individuals (Table 2.3). Respondents cultivated approximately 4.3 ha in the last growing season across all crops, of which half a hectare was planted to beans. Approximately 23% of the respondents purchased bean seed from an agro-input supplier in the last season and approximately 68% of farmers planted an improved bean variety.

Table 2.3: Bean sample demographic and agricultural characteristics

Variable (N=262)	Mean	Std. Dev.
Household Head (HH) (%)	76.72	(42.34)
Female (%)	41.60	(49.38)
Age	51.24	(14.25)
Respondent completed secondary school (%)	56.49	(49.67)
Respondent's main source of employment: own farming (%)	87.79	(32.81)
Household Size (Total)	4.78	(2.01)
Agricultural		
Total land area cultivated (ha)	4.31	(12.99)
Total bean land area cultivated (ha) last season	0.50	(1.45)
Purchased bean seed last season from an agro-dealer (%)	22.90	(42.10)
Average number of bean varieties grown in last season	1.13	(0.50)
Respondent self-reported growing an improved bean variety last season (%)	68.08	(0.47)
Bean in two most important crops grown for HH consumption (%)	64.89	(47.82)
Bean in two most important crops grown for HH income (%)	59.54	(49.18)
Already purchased some bean seed for planting in coming season (%)	11.07	(31.43)
Has received or expects to receive seed from the government? (%)	12.21	(32.81)
Current Levels of Aspirations Dimensions		
Monthly Average Agricultural Revenue (USD)	62.66	(89.28)
Agricultural Assets Value (USD)	2014.31	(3760.45)
Agricultural Social Status (1 to 5, 5=Highest)	3.10	(0.58)
Average Years of Adult HH Members' Education	10.49	(2.21)
Average Adult HH Members' Health & Well-being (1 to 5, 5=Highest)	3.56	(0.64)

*Note: During time of survey, November-December 2022, 1USD=646.24 Zimbabwean dollars (zimra.co.zw).

Table 2.4 outlines the average unweighted aspirations value across the five aspirations dimensions. Monthly aspired agricultural revenue is $500 USD, aspired agricultural social status is a 4 out of 5, average aspired years of education children will obtain is approximately 15 (the equivalent of completing a portion of college education), while aspired health/wellbeing of children is a 4 out of a possible 5. Across the aspirational dimensions, agricultural asset value, children's education, and children's wellbeing are weighted around 20%, aspired agricultural social status is weighted at approximately 17%, and aspired monthly agricultural revenue is weighted at approximately 24%.

Table 2.4: Unweighted Aspirations Dimension Value and Weight

	Aspiration Value		Aspiration Weight (%)	
Dimension (n=262)	Mean	Std. Dev.	Mean	Std. Dev.
Monthly Average Agricultural Revenue (USD)	508.30	1423.36	23.68	12.15
Agricultural Assets Value (USD)	15527.31	41854.76	19.51	7.22
Agricultural Social Status (Scale 1-5; 5=Highest)	3.99	0.75	16.69	5.84
Average Years of Children's Education (15 years & under) *	14.93	2.74	20.40	8.49
Children's Health & Well-being (18 & under), (Scale 1-5; 5=Highest) *	4.10	0.68	19.73	6.65

*For households that did not have a child under 15 (18) years of age, their missing value was replaced with the mean value as to not drop these observations (n=43).

4. Results and Discussion

Based on descriptive results, not controlling for variables other than round and bean type, the total WTP bids for Gloria do not significantly differ across bidding rounds by parametric or non-parametric equality tests (Table 2.5). However, this does not hold true for NUA45 without the nutrition label or for NUA45 with the nutritional label. WTP for NUA45 with no nutrition label is $4.38/2kg in round 1 of bidding, increases to $5.17/2kg in round 2, and tops out at $5.69/2kg. WTP, on average, for NUA45 with the nutrition label is $5.15/2kg in round 1, increases to $6.23/2kg in round 2, and is $6.94/2kg in round 3. Therefore, based on descriptive results, the information shared in rounds two and three impacts farmer WTP for the biofortified seeds. Within each round, farmers' WTP is lowest for Gloria and highest for NUA45 with the nutrition label, which is significantly different from one another at the 1% level.

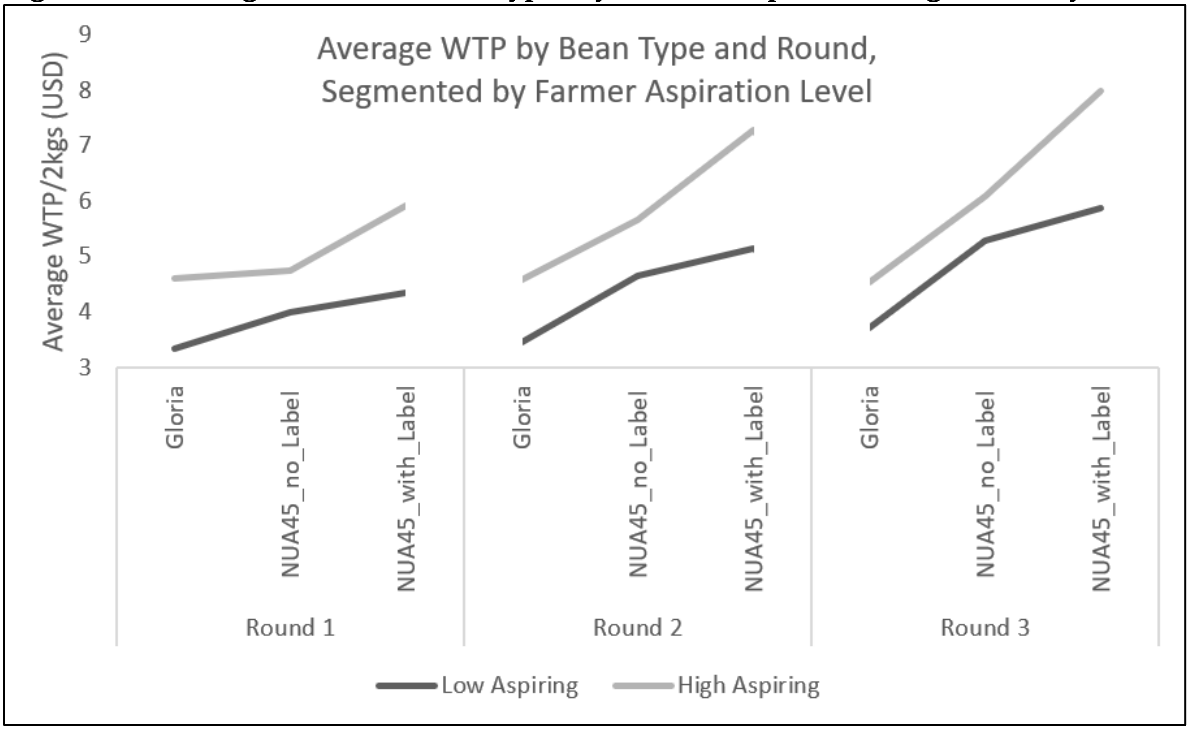
Table 2.5: Mean WTP by round and bean type for 2kg seed pack

	Round 1	Round 2	Round 3	P-values	
				F-Tests	K-Tests
Gloria	3.98	4.02	4.13	0.8550	0.4442
	(3.83)	(2.91)	(2.77)		
NUA45 no label	4.38	5.17	5.69	0.0001	0.0001
	(2.89)	(3.63)	(3.93)		
NUA45 with label	5.15	6.23	6.94	0.0000	0.0001
	(4.01)	(4.64)	(4.67)		
P-values: F-Tests	0.0009	0.0000	0.0000	--	--
K-Tests	0.0001	0.0001	0.0001	--	--
Observations (N)	262	262	262		

Note: standard errors are in parenthesis. F-tests comes from the parametric equality of means tests while K-tests come from the non-parametric Kruskal-Wallis rank test.

The average WTP for bean seed type by high versus low aspiring farmers by round is outlined in Figure 2.1. We find that high aspiring farmers are willing to pay a higher price for every bean seed type in every round, compared to low aspiring individuals. The difference in WTP is significantly different at the 1% level between high and low aspiring farmers for Gloria (in round 1 and 2), NUA45 with the label (in all rounds). The WTP difference between farmer aspirations levels is significantly different at the 5% level for NUA45, no label (round 1 and 2), and Gloria (round 3).

Figure 2.1: Average WTP for Bean Types by Farmer Aspiration, Segmented by Round



4.1 Impact of Information within Rounds

To account for potential covariates in WTP, econometric results assessing the differences in average WTP for 2kgs of seed across bean types within each round are outlined in Table 2.6. Within round 1, compared to the base bean type, NUA45 without the nutrition label, Gloria is discounted by \$0.40, ($p<0.05$), indicating farmers prefer the purple-mottled color of the NUA45 bean compared to the cream color of Gloria, as all other observable attributes are similar between the two beans. The "iron and zinc enriched" label for NUA45 with the label, garners on average, a premium of \$0.77, ($p<0.01$), compared to NUA45 without the nutrition label. Compared to the average WTP for Gloria, farmers are willing to pay an additional \$1.17, ($p<0.01$) for NUA45 with the nutrition label. In model 2, farmers that are considered low-aspiring, discount Gloria -\$0.65 compared to NUA45 without the nutrition label while they are willing to pay \$0.36 premium for NUA45 with the label compared to NUA45 without the label. However, farmers that are high-aspiring are willing to pay an additional \$0.82 for NUA45 with the nutrition label (p<0.01).

Within round 2, the difference in average WTP between the bean types increases with Gloria being discounted by more than $1 while NUA45 with the nutrition label has a premium greater than $1 compared to NUA45 without the nutrition label (model 1). NUA45 with the nutrition label receives an average premium of $2.20 (p<0.01) compared to Gloria. For high-aspiring farmers, they are willing to pay an additional $1.13, (p<0.01) for NUA45 with the nutrition label compared to NUA45 without the nutrition label. Finally, in round 3, averaging across both low and high aspiring farmers, farmers discount Gloria by $1.56 and are willing to pay a premium of $1.24 for NUA45 with the nutrition label compared to NUA45 without the nutrition label. Low-aspiring farmers discount Gloria by $1.59 (p<0.01), yet are willing to pay a premium of $0.57 (p<0.01) for NUA45 with the label compared to NUA45 without the nutrition label. High-aspiring farmers are willing to pay an additional $1.34 (p<0.01) for NUA45 with the nutrition label compared to NUA45 without the nutrition label.

Table 2.6: Average WTP within Rounds across Bean Type

	ROUND 1						ROUND 2						ROUND 3					
	Model 1			**Model 2**			**Model 1**			**Model 2**			**Model 1**			**Model 2**		
	Coef.	SE		Coef.	SE		Coef.	SE		Coef.	SE		Coef.	SE		Coef.	SE	
Constant (BF, no label)	4.38	0.09	***	4.38	0.09	***	5.17	0.08	***	5.16	0.08	***	5.69	0.08	***	5.69	0.08	***
Bean Type																		
Gloria (non-BF bean)	-0.40	0.16	**	-0.65	0.14	***	-1.14	0.13	***	-1.21	0.14	***	-1.56	0.16	***	-1.59	0.19	***
NUA45 with label (BF)	0.77	0.15	***	0.36	0.14	***	1.06	0.16	***	0.49	0.15	***	1.24	0.15	***	0.57	0.17	***
Interaction Terms																		
Gloria x HA	--			0.50	0.33		--			0.12	0.26		--			0.06	0.33	
NUA45 w/ label x HA	--			0.82	0.30	***	--			1.13	0.30	***	--			1.34	0.30	***
Farmer Fixed Effects?	Yes			Yes			Yes			Yes			Yes			Yes		
Post-estimation Tests																		
NUA w/ label - Gloria = 0	1.17	0.18	***	1.01	0.14	***	2.20	0.16	***	1.70	0.17	***	2.80	0.20	***	2.16	0.19	***
High Aspiring (HA) Interactions																		
HAxNUA w/ label - HAxGloria = 0				0.32	0.36					1.01	0.31	***				1.28	0.40	***
# of Observations	786			786			786			786			786			786		
# of Respondent	262			262			262			262			262			262		
Within R-Squared	0.0918			0.1029			0.2989			0.3227			0.3391			0.3636		

Notes: *= p<10%, **=p-value <5%, ***=p-value <1%. B = NUA45, the biofortified bean seed. HA=high aspiring farmers.

4.2 Incremental Impact of Information within Bean Type

Next, we compare average WTP across rounds for each bean type to assess the incremental and cumulative impact of information in rounds 2 and 3 (Table 2.7). Similar to what is shown in descriptive analysis, there is no significant difference in average WTP for Gloria across rounds. Once farmer aspirations are included, Gloria receives a premium of $0.36 compared to round 1, for low-aspiring individuals ($p<0.01$), which is counter-intuitive to what we would expect as no new information was shared about Gloria. For high-aspiring farmers, there is no statistical difference in WTP for Gloria round 2 and 3 bids compared to round 1.

The incremental impact of nutrition information in round 2 for NUA45 without the nutrition label is $0.65 ($p<0.01$) for low-aspiring farmers. The incremental impact of sharing consumption information about NUA45 in round 3 from round 2 on farmer WTP is $0.65 ($p<0.01$, shown as a post-estimation section of the table). The cumulative increase in farmer WTP for NUA45 without the nutrition label from round 1 to 3 is $1.31 for low-aspiring farmers. Though high-aspiring farmers are willing to pay an additional amount on top of what low-aspiring farmers were willing to pay in round 2 and 3, it is not statistically significant.

Across all farmers (model 3), for NUA45 with the nutrition label, the incremental impact of nutrition information shared in round 2 increased farmer WTP by $1.08 compared to round 1, ($p<0.01$). The incremental impact of NUA45 consumption information shared in round 3 results in an incremental increase of $0.71 from round 2 and a cumulative increase of $1.79 (both $p<0.01$). Parsing results by farmer aspirations (model 4), low-aspiring farmers are willing to pay a premium of $0.79 in round 2 compared to round 1 and cumulatively, a premium of $1.51. In addition to the $0.79 premium low-aspiring farmers are willing to pay for NUA45 with the label for round 2 information, high aspiring farmers are willing to pay an additional $0.58.

Table 2.7: Impact of Information Rounds on Average WTP within Bean Type

	GLORIA						NUA45 NO LABEL						NUA45 WITH LABEL					
	Model 3			**Model 4**			**Model 3**			**Model 4**			**Model 3**			**Model 4**		
	Coef.	SE		Coef.	SE		Coef.	SE		Coef.	SE		Coef.	SE		Coef.	SE	
Constant (Round 1)	3.98	0.10	***	3.98	0.10	***	4.38	0.08	***	4.38	0.09	***	5.15	0.10	***	5.15	0.10	***
Round																		
Round 2 (R2)	0.04	0.14		0.10	0.09		0.79	0.12	***	0.65	0.12	***	1.08	0.12	***	0.79	0.11	***
Round 3 (R3)	0.15	0.18		0.36	0.13	***	1.31	0.15	***	1.30	0.18	***	1.79	0.20	***	1.51	0.16	***
Interaction Terms																		
R2 x High Aspiring	--			-0.11	0.28			--		0.27	0.24		--			0.58	0.23	**
R3 x High Aspiring	--			-0.42	0.36			--		0.03	0.30		--			0.54	0.39	
Farmer Fixed Effects?	Yes			Yes			Yes			Yes			Yes			Yes		
Post-estimation Tests																		
R3 - R2 = 0	0.11	0.12		0.26	0.11	**	0.53	0.08	***	0.65	0.11	***	0.71	0.14	***	0.73	0.11	***
High Aspiring Interactions																		
HA,R3–HA,R2 = 0				-0.31	0.24					-0.24	0.15					-0.04	0.29	
# of Observations	786			786			786			786			786			786		
# of Respondents	262			262			262			262			262			262		
Within R-Squared	0.0021			0.0061			0.1906			0.1930			0.2050			0.2117		

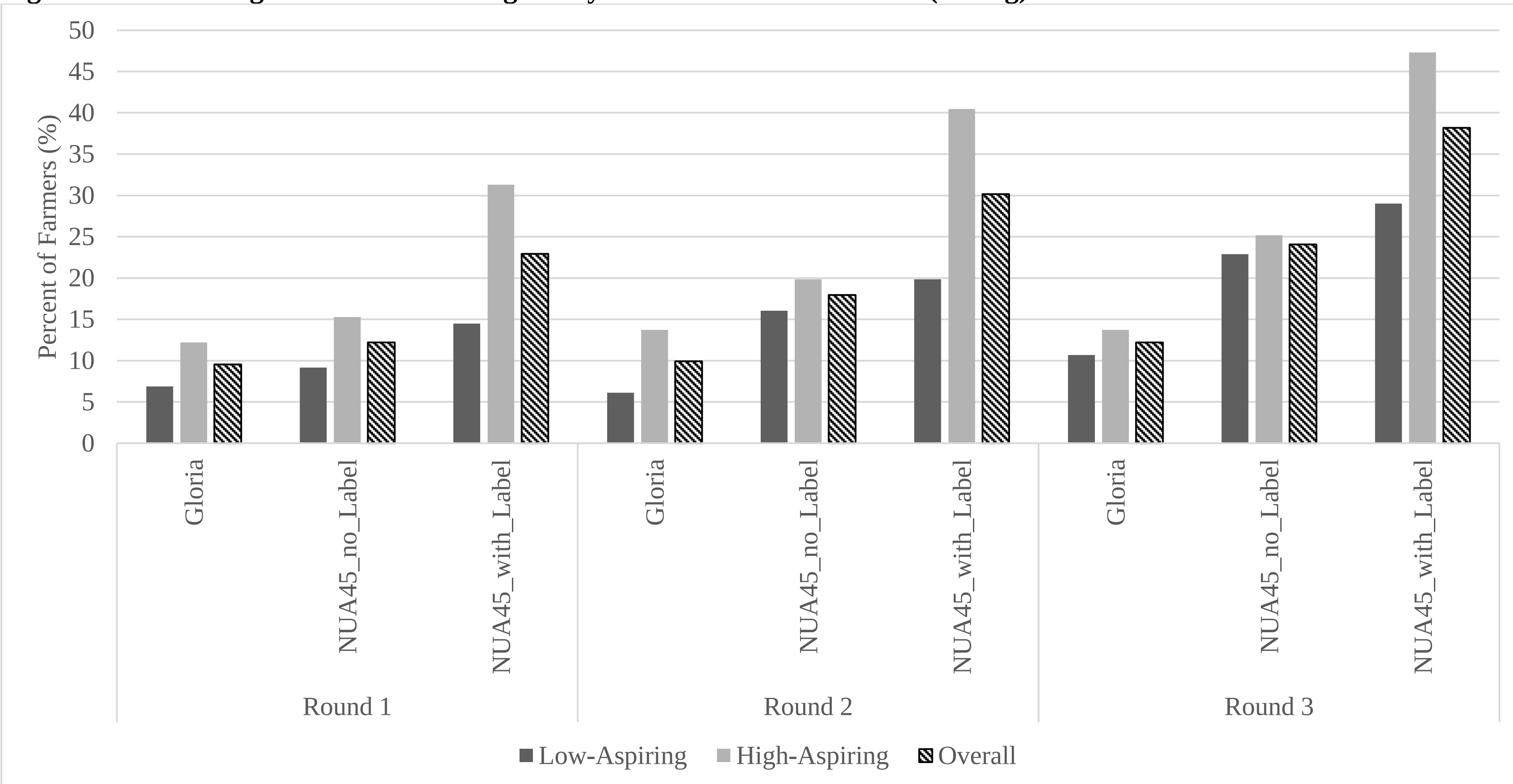
Notes: *= p<10%, **=p-value <5%, ***=p-value <1%.

4.3 Effective Demand Estimation Results

On average the share of farmers that are willing to pay at or above the market price ($7.00/2kg) is lowest in round 1 and highest in round 3 (Figure 2.2). There is great heterogeneity across the different bean seed types within each round with the smallest percentage being for Gloria and highest being for NUA45 with the nutrition label. Further, there is heterogeneity between low and aspiring farmers with a higher percentage of high aspiring farmers for each bean type and in each round being willing to pay at or above the market price compared to low aspiring farmers.

Given these results, it is recommended that seed companies include nutrition labeling on NUA45 seed packs as well as the additional information (via signage, pamphlets, etc.) provided in rounds 2 and 3 (iron and zinc deficiency rates in Zimbabwe and their impacts, the percentage of these micronutrients met by NUA45, as well as consumption information). Further, seed companies and/or extension staff should target high aspiring farmers as a higher percentage are willing to pay at or above the market price compared to low aspiring farmers (47% versus 29%, respectively for NUA45 with the label in round 3).

Figure 2.2: Percentage of Farmers Willing to Pay at or Above Market Price ($7/2kg)



4.4 Observable Characteristic Predictors of High Aspiring Individuals

To determine which observable characteristics correlate to a farmer being considered high aspiring in this sample, we test equality differences in means across the demographic characteristics comparing low and high aspiring farmers (Table 2.8). We segment the analysis into areas of household demographics, agricultural demographics, group membership and/or training participation, and current levels of the dimensions assessed for the aspirations index. Within household demographics, a higher percentage of high aspiring farmers have completed schooling above the primary level compared to low aspiring farmers (70% versus 43%, respectively, $p<0.01$). High aspiring farmers appear to have a higher wealth status than low aspiring farmers as there is a statistically higher percentage of low aspiring individuals in the third wealth quartile (out of four) versus high aspiring individuals ($p<0.10$), and a statistically lower percentage of low aspiring farmers in the fourth wealth quartile (the highest quartile) compared to high aspiring farmers ($p<0.10$). Across geographic provinces, more high aspiring farmers reside in Manicaland than low aspiring farmers ($p<0.05$), while more low aspiring farmers reside in Mashonaland Central as well as Midlands than high aspiring farmers ($p<0.10$ and $p<0.05$, respectively).

Only one agricultural demographic significant difference exists between high and low aspiring farmers. On average, high aspiring farmers cultivated a much larger land area across all crops than low aspiring farmers, 6.5 ha versus 2.13 ha ($p<0.01$). Assessing group membership and/or participation in trainings within the six months prior to the survey yields significant differences between low and high aspiring individuals for three characteristics: savings group membership, religious group membership, and participation in a farmer field day. A statistically higher percentage of high aspiring compared to low aspiring farmers belonged to saving groups

($p<0.05$), attended farmer field days ($p<0.05$), and belonged to a religious group ($p<0.01$). Finally in terms of current levels of dimensions asked about in the aspirations index, high aspiring individuals had a higher perceived agricultural social status, adult household members had achieved more years of formal education, and they had a higher perceived health status of adult household members' than low aspiring farmers (all with $p<0.01$).

Therefore, if the government, private seed companies or NGO programs were to target high aspiring farmers to increase demand for biofortified bean seed, we would suggest focusing on these outward characteristics. Specifically, we suggest targeting efforts be oriented toward farmers with education achieved above the primary level, those that have a higher wealth status in communities, cultivate larger plots of land among multiple crops, and are likely agricultural leaders within their community (i.e., have high social status). In terms of geographic preference for initial targeting efforts, we suggest focusing first in the Manicaland province. Finally, targeting farmers that are part of a savings group as well as are part of a religious group would be advantageous to reaching high aspiring farmers based on the results here, along with those that attend farmer field days.

Table 2.8: Sample demographics and characteristics for Low vs. High Aspiring Farmers

	Low Aspiring		High Aspiring		Equality of means
Variable (N=262)	Mean	Std. Dev.	Mean	Std. Dev.	p-value
Household Head (HH) (%)	80.92	39.45	72.52	44.81	0.109
Female (%)	36.64	48.37	46.56	50.07	0.104
Age	51.54	14.40	50.95	14.15	0.736
Respondent completed secondary school (%)	42.75	49.66	70.23	45.90	<0.001
Respondent's main source of employment: own farming (%)	90.08	30.01	85.50	35.35	0.259
Household Size (Total)	4.73	2.02	4.83	2.01	0.668
Wealth Index Quart 1 (Lowest)	25.95	44.01	24.42	43.13	0.777
Wealth Index Quart 2	23.66	42.67	25.95	44.01	0.669
Wealth Index Quart 3	30.53	46.23	20.61	25.57	0.066
Wealth Index Quart 4 (Highest)	19.85	40.04	29.01	45.55	0.085
Province = Manicaland	16.79	37.52	29.01	45.55	0.019
Province = Mashonaland Central	32.82	47.14	22.91	42.18	0.074
Province = Mashonaland East	11.45	31.96	16.03	36.83	0.283
Province = Mashonaland West	25.19	43.58	19.09	39.45	0.236
Province = Masvingo	6.87	25.39	11.45	31.96	0.200
Province = Midlands	6.87	25.39	1.53	12.31	0.031
Agricultural					
Total land area cultivated (ha)	2.13	1.78	6.50	18.05	0.006
Total bean land area cultivated (ha) last season	0.45	0.48	0.54	1.95	0.661
Average number of bean varieties grown in the last season	1.13	0.58	1.13	0.43	0.957
Respondent grew an improved bean variety last season (%)	71.29	45.47	65.18	47.85	0.342
Bean in two most important crops grown for HH consumption (%)	67.18	47.14	62.60	48.57	0.439
Bean in two most important crops grown for HH income source (%)	54.96	49.94	64.12	48.15	0.132
Aware of NUA45 prior to survey (0/1)	29.77	45.90	36.64	48.37	0.239
Group Membership or Trainings Attended					
Farmer Group (0/1)	40.46	49.27	35.11	47.92	0.374
Farmer Cooperative (0/1)	13.74	34.56	12.98	33.73	0.857
Savings Group (0/1)	9.16	28.96	17.56	38.19	0.046
Participated in Farmer Field Days (0/1)	21.37	41.15	34.35	47.67	0.019
Participated in Farmer Field Schools (0/1)	12.98	33.73	13.74	34.56	0.857
Participated in Health/Nutrition Programs (0/1)	7.63	26.66	8.40	27.84	0.821
Religious Group (0/1)	19.85	40.04	38.93	48.95	0.001

Table 2.8 (cont'd)

	Low Aspiring		High Aspiring		Equality of means
Variable (N=262)	Mean	Std. Dev.	Mean	Std. Dev.	p-value
Current Levels of Aspirations Dimensions					
Monthly Average Agricultural Revenue (USD)	66.22	91.02	59.09	87.93	0.519
Agricultural Assets Value (USD)	1857.87	3097.00	2170.75	4338.50	0.502
Agricultural Social Status (1 to 5, 5=Highest)	2.98	0.55	3.21	0.58	0.0010
Average Years of Adult HH Members' Education	9.97	2.13	11.00	2.19	<0.001
Avg. Adult HH Members' Health & Well-being (1-5, 5=Highest)	3.36	0.58	3.76	0.64	<0.001

Note: *= p<10%, **=p-value <5%, ***=p-value <1%.

5. Policy Implications and Conclusions

Aspirations are increasingly being used in economics research to better understand individual decision making. Previous studies have found that aspirations are important in influencing future-oriented behavior including higher investments in school enrollment, nutrition, occupation type, employment income, and uptake of specific agricultural practices (Macours and Vakis, 2009; Beaman et al., 2012; Knight and Gunatilaka, 2012; Bernard and Taffesse, 2014; Knapp, 2022). We investigate aspirations in the context of willingness-to-pay (WTP) for biofortified bean seeds and a benchmark seed in rural Zimbabwe with 262 farmers using a within-subjects experiment. Specifically, we assess if farmers classified as being high aspiring, based on a five-dimension aspirations index, have a higher WTP for biofortified bean seeds than low aspiring farmers and if they respond differently, as evidenced by their WTP, to nutrition and cooking quality information shared about the various bean seed types, via three rounds of bidding.

For the product intervention, we use biofortified bean seeds, NUA45, with and without nutrition labels, along with a benchmark variety, Gloria, because the government of Zimbabwe is promoting and delivering biofortified bean seeds as one method to address the high levels of zinc and iron deficiency in the country. However, the health benefits of consuming biofortified beans are not realized immediately and can be viewed as a medium-term investment, hence the inclusion of farmer aspirations into the WTP experiment.

Results indicate that the highest premium is given for the NUA45 biofortified bean with the nutrition label followed by NUA45 without the nutrition label. Farmers do respond in positive and significant ways to both nutrition and consumption attribute information for both biofortified bean types. Further, high aspiring farmers place an additional premium on NUA45 with the nutrition label compared to the other bean types in all rounds. Additionally, high aspiring farmers are willing to pay a premium for the nutrition label in round 1 and for the nutrition deficiency information shared by enumerators in round 2 compared to low aspiring farmers.

As iron and zinc are invisible to the eye and therefore credence attributes, these results confirm the need for seed companies to label NUA45 as "iron and zinc enriched" to (1) identify its benefits, and (2) obtain a premium price. We also recommend agro-dealers and extension agents communicate the rates and impacts of iron and zinc deficiencies and biofortified bean nutrition benefits as well as NUA45 consumption information either on, inside, or with the seed packs, or via signage near the seed packs in the shop. Further, high aspiring individuals are most responsive to the NUA45 bean with the nutrition label and with the information shared. Therefore, for initial targeting and roll-out of these seeds, we recommend agro-dealers and extension agents target farmers that have achieved above a primary school education, that farm larger total land area across all crops, are asset-wise more well-off, participate in farmer field days, are part of a savings group, and are members of a religious group, as these characteristics statistically set-apart high aspiring farmers from low aspiring farmers.

A potential limitation of this study is the possibility of measurement error from the agricultural revenue and agricultural asset data collected for the aspirations index which may result in downward biased coefficient estimates. Though we asked about agricultural revenue by irrigated and rainfed seasons for better recall, we did not ask by each crop grown, only at an aggregate level which may have been difficult for farmers to provide. Additionally, we asked about agricultural asset values in aggregate and not asset by asset which would have likely given a more refined estimate. In the future, if time and logistics allow, we recommend enumerators step through this process in a more detailed manner with respondents.

Future research can explore different dimensions included in the aspirations index to assess the sensitivity of results given different categories. Regarding the information shared for NUA45, conducting a cost-benefit analysis of the costs associated with either labeling, printing pamphlets, or providing signage to communicate this information compared to the benefit the agro-dealers (and seed companies) would receive from the increased number of farmers willing to pay premium price would be useful to inform business strategies. Finally, one could test varying degrees of nutrition and consumption information on farmer WTP to determine the ideal message length for farmers.

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APPENDIX

A.1 Aspiration Questions

Below outlines the questions asked to assess current and aspired levels for each dimension.

Table A.1.1: Aspirations Dimension Questions

Section A: Agricultural Revenue	
A.1	For how much (in USD) did you sell the crops harvested in the last irrigated agricultural season (June to September 2022)?
A.2	For how much (in USD) did you sell the crops harvested in the last rainfed agricultural season (October 2021 to March 2022)?
A.3	Based on your previous answers, your average monthly agricultural revenue is estimated as [x]. What is the monthly agricultural income you would like to achieve in your life?
Section B: Agricultural Assets	
Interviewer read: I would now like to ask you about the agricultural assets which your household owns. Assets are any object or item which has monetary value. Examples include the value of your agricultural land, livestock, storage facilities, machinery, etc.	
B.1	Think about how your agricultural assets. What is your estimated value (in USD) of your agricultural assets?
B.2	What is the agricultural asset value you would like to achieve in your life?
Section C: Social Status in Agriculture	
Interviewer read: Having a high level of social status in agriculture means that people from your community ask for advice from you in key matters related to agriculture. People respect you, and your opinion influences important decisions.	
C.1	What is the level of social status related to agriculture you have at present? [5] Very High, [4] High, [3] Moderate, [2] Low, [1] Very low
C.2	What is the level of social status related to agriculture would you like to achieve in your life? [5] Very High, [4] High, [3] Moderate, [2] Low, [1] Very low
Section D: Family Education	
Interviewer read: Now I would like to talk to you about education levels of your family members who are 15 years and older and the levels of education you hope those under 15 years of age in your family will achieve.	
D.1	Of the household members age 15 or older you said live in this household, please tell me what is the number of completed years of formal education for [member]?
D.2	What is the number of completed years of formal education, on average, that you would like, or hope for, the younger generation (under 15 years of age) of males in your family to eventually achieve?
D.3	What is the number of completed years of formal education, on average, that you would like, or hope for, the younger generation (under 15 years of age) of females in your family to eventually achieve?
Section E: Physical Health and well-being of children in your family	
Interviewer read: Having a very high level of physical health and wellbeing means that you very seldom get sick, feel strong, are the weight and height you should be for your age based on doctor's recommendations, eat the correct number of calories required for your body in a day (not too much, not too little) as well as nutritious foods, and you do not tire easily. In contrast, having a very low level of physical health means that get sick easily and have a weak immune system, feel tired often, feel weak, often do not eat the correct amount or variety of food to properly fuel your body which may negatively impact your life.	
E.1	What is the average level of physical health and wellbeing adult (18 years of age or older) male members in your family have at present? [5] Very High, [4] High, [3] Moderate, [2] Low, [1] Very low

Table A.1.1 (cont'd)

E.2	What is the average level of physical health and wellbeing adult (18 years of age or older) female members in your family have at present? [5] Very High, [4] High, [3] Moderate, [2] Low, [1] Very low
E.3	What is the average level of physical health and wellbeing that you would like, or hope for, the males under 18 years of age in your family to eventually achieve? [5] Very High, [4] High, [3] Moderate, [2] Low, [1] Very low
E.4	What is the average level of physical health and wellbeing that you would like, or hope for, the females under 18 years of age les in your family to eventually achieve? [5] Very High, [4] High, [3] Moderate, [2] Low, [1] Very low

A.2 Information Script (English versions)

<u>Round 1:</u> respondents observe the seed packs, as shown below.

Figure A.2.1: Bean Seed Packs used in Experiment

<u>Round 2:</u> ***Enumerator read:*** Iron deficiency is a severe public health issue in Zimbabwe as approximately 7 out of 10 children and 6 out of 10 women of reproductive age suffer from iron deficiency. Iron deficiency can impair the mental development and learning capacity of children, increase weakness and fatigue, and increases the risk of childbirth complications for the baby and mother. Further, zinc deficiency is also a severe public health concern in Zimbabwe as 1 in 2 individuals are at risk of inadequate zinc intake. Zinc deficiency can impair proper physical growth which can lead to stunting, impair cognitive development, and can cause a weak immune system. Consuming iron and zinc enriched beans can contribute a higher amount of daily iron and zinc needs compared to consuming beans not enriched with these nutrients.

<u>Round 3:</u> ***Enumerator read:*** Researchers in Zimbabwe have evaluated the cooking quality of NUA45 beans, the same as the variety presented to you here today. They have found that NUA45 produces a thick soup and the seed swells almost twice their size when cooked. The cooking time for NUA45 grain to become tender, is a little over 1 hour. Compared to other bean varieties, more consumers rated the taste of NUA45 beans as excellent.

A.3 Sampling for the Nationally Representative Bean Study

As this study was part of a larger nationally representative bean farmer survey, the initial sampling leans on its sampling procedure. First, a sampling frame was obtained from the AGRITEX (Zimbabwe Agricultural and Extension Department) office of land allocated to beans at the ward level (administrative level below province) in the 2021 growing season. In the first stage, within each province, wards were randomly selected, conditional on the ward having a minimum of 45 hectares of total bean land area. The number of wards selected within each province was proportional to bean land area size of the province as a percentage of total bean land area in the country. In stage 2, villages per ward were then randomly selected. Once the enumerator teams arrived in each village, they first listed all bean growing households. Following this, 12 households and six replacement households were randomly selected to be interviewed for the main survey portion of the study. The bean experimental auction carried out in this study was implemented within a sub-sample of the main survey respondents. To select the specific villages where the experiment was to be carried out, we randomly selected villages stratified by provinces. Within each village, 12 households participated in the experiment.

A.4 Household Asset Index

A household asset index was developed as a proxy for household economic status as we did not collect household income or expenditure data. Specifically, a wealth module from the survey which asked about household items, farm, and livestock asset ownership is used to construct a household asset count index. As the financial importance of each of these items is different, we adjust the count of each item by their economic contribution (e.g., weight) following the procedures outlined by the Gates Foundation's Agricultural Development Outcome Indicators (2010) and Njuku et al. (2011). The resulting scores for each household are divided into quartiles where quartile one represents the lowest asset score and quartile four represents respondents having the highest asset score.

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CHAPTER 3. THE EFFECTS OF BID QUANTITY ON FARMER WILLINGNESS-TO-PAY FOR BIOFORTIFIED BEAN SEEDS IN ZIMBABWE

1. Introduction

Experimental auctions are commonly used to elicit willingness-to-pay (WTP) for novel products. In the past decade, many aspects of various auction methods have been studied to ensure responses obtained give an unbiased estimate of demand for a specific product. Such studies have examined auction type, the number of rounds, the number of participants in a bidding group, and the endowment effect, among other factors (Lusk and Shogren, 2007; Canavari et al., 2019). Despite gains made in the literature, some issues regarding the method remain insufficiently addressed. This study addresses one area that has received little attention to date: the use of fixed and at times arbitrary experimental quantities when eliciting unit-level WTP values.

Typically, in preference elicitation studies, researchers pre-specify the quantity of a product that becomes the unit for which respondents formulate their bid and hold this quantity constant across product choices. The use of this pre-specified quantity has been justified under the assumption that individuals are rational, and their preferences are stable (Maredia and Bartle, 2022); therefore, any quantity can be considered an experimental quantity. Thus, WTP values can be scaled from the results of a small-unit WTP by multiplying the per-unit bid by the number of units of interest. However, several studies have shown that individuals' preferences are not fully rational, and reversals (e.g., A is preferred to B in one response but B is preferred to A in another response) sometimes occur as first noted by Grether and Plot (1979). This can occur because individuals' preferences are often constructed during the process of elicitation and can depend upon issues including experimental settings, risk aversion, and inattention (Slovic, 1995; Camerer and Loewenstein, 2003; Harrison et al., 2003; Lusk and Shogren, 2007; Balcombe et al., 2018; O'Donnell and Evers, 2019).

Experiments often use a pre-specified quantity that matches the smallest unit of the good available in the market, such as a pint of milk or a kilogram pack of seed. Yet this may not reflect respondents' intended purchase quantities which may be less than, equal to, or greater than the pre-specified experimental quantity used. For most consumer goods, using smaller quantities may not be a serious issue as they are often purchased in small quantities due to perishability or cash constraints. Therefore, small quantities used in consumer WTP studies may be the modal quantities purchased in the market. The same may not be true for producer WTP studies as farmers often purchase larger quantities of production inputs with those purchases concentrated at certain times of the year. This can create situations where the intended purchase quantity for the majority of respondents is likely greater than the experimental quantity. However, due to researchers' budget constraints and logistical reasons, producer experiments often use the smallest quantity units, which may not fully reflect actual market purchase decisions.

The need for bid quantity research was first noted by Corsi (2007) in the context of non-market valuations. Varying quantities have been incorporated into hypothetical discrete choice experiments, an alternative method to experimental auctions, largely by implementing open-ended choice experiments (OECE). In OECEs, participants state the quantity demanded for each good at different price combinations. Resulting OECE estimates were consistent with prior expectations and purchasing behavior when compared to traditionally designed experimental auctions (Corrigan et al., 2009) and choice experiments (CEs) (Dennis et al., 2021). Further, recent hypothetical CE research shows WTP estimates may be biased with consumers over-stating per-unit WTP when the elicitation question is framed with a small quantity base versus a larger quantity base if the experimental quantity is significantly different than their typical purchase quantity (Lin et al., 2022). This has been attributed to a behavioral bias that can arise from mental budgeting (Lin et al., 2022).

There is a lack of research on bid quantity in experimental auctions. The few non-hypothetical experimental auction studies focused on bid quantity have examined the impact of quantity on bidding outcomes in multi-unit scenarios, but they relied on pre-specified quantities. These studies have typically taken one of three paths: (1) bidding for multiple pre-specified quantities of the same product at the same time (e.g., Akaichi et al., 2012), (2) via incremental pre-specified product quantity increases with each additional bidding round (e.g., Elbakidze et al., 2013), or (3) adding the quantity question post-experimental elicitation on WTP for a fixed quantity (e.g., Maredia and Bartle, 2022). These studies' objectives were to estimate and/or confirm the presence of demand reduction, diminishing marginal value of an additional unit, demand schedules, and total product demand; however, they only partially address the bid quantity question. What remains unexplored is whether an individual's per-unit WTP is tied to the total intended purchase quantity, and if it is, whether experiments that use a fixed quantity that is significantly different from the intended purchase quantity give biased WTP estimates.

Using a case study of different varieties of bean seed in rural Zimbabwe, we designed a non-hypothetical experiment to assess the extent of this bias. Specifically, we address two research questions. First, what is the impact of varying the experimental quantity used in bid elicitation on per-unit WTP, using a pre-specified fixed quantity versus when respondents match their experimental quantity to their intended purchase quantity? Second, do the per-unit WTP differences attributed to experimental quantity vary according to seed type (the commonly purchased/available benchmark seed versus the novel seed)?

This study makes multiple contributions to the literature. First, we evaluate WTP for equal-sized seed packs across different experimental quantities in a non-hypothetical, real field experiment using the incentive-compatible Becker-DeGroot-Marschak (BDM) auction-like mechanism (Becker, DeGroot and Marschak, 1964). We randomly assign producers to one of two treatment groups - a fixed quantity group (FQG) where they bid on 2kg seed packs or a variable quantity group (VQG) where producers bid on their intended purchase quantity. The VQG is a proposed experimental design which eliminates the potential bias arising from mental budgeting (any difference in experimental quantity and intended purchase quantity). We compare the per-unit WTP across these two treatment groups to assess if, and the degree to which, the bias from mental budgeting explains the difference. Our resulting analyses allow researchers designing future real experimental auctions to weigh the potential WTP bias arising from mental budgeting against logistical challenges and the costs of having respondents set their own experimental quantity.

Second, contrasting the existing literature, our inquiry focuses on producers and follows the theoretical framework of estimating producer WTP proposed by Lusk and Hudson (2004) and extended by Zapata and Carpio (214) and Yue et al. (2017). In this context, we assume farmers derive utility when profits are increased, whereby profit maximization is a function of expected revenues and costs (similar to Rosch and Ortega, 2018; Maredia & Bartle, 2022, and Win et al., 2022). The quantity question is of special interest in the context of producers' WTP for inputs like seed and fertilizer, which are commonly purchased in larger quantities (Maredia et al., 2019; Ward et al., 2020). Finally, we examine varying bid quantity and producer WTP in a developing country context, Zimbabwe, a departure from previous bid quantity studies that largely occurred in developed or emerging economies (Dennis et al., 2021, Lin et al., 2022). In contrast to developed country settings, respondents in developing countries may think more critically about their bid formulation since the price of the goods in question represent a higher proportion of their disposable income.

We address our research question by focusing on Zimbabwean farmers' WTP for three different types of bean seed representing two varieties. One is the benchmark bean variety that has been available in the market for many years while the other is a novel biofortified variety, conventionally bred to have higher levels of zinc and iron. This biofortified bean is being promoted by the Zimbabwean government to help address iron and zinc deficiencies in the country. Seeds of this variety are being distributed through private seed companies who rely on unbiased WTP estimates for market demand when establishing pricing strategies. In our experiment, we use two variations of product labeling for this biofortified variety—one with only the variety name on the package (as currently sold) and the other with an additional 'iron and zinc enriched' label (a novel feature not yet reflected in product marketing). In addition to overall analyses pooled across bean types, we explore mental budgeting bias by bean seed types to assess if previous awareness and/or purchase experience of the benchmark bean impact the precision of WTP bids compared to bids stated for the novel seeds.

The remainder of this paper is organized as follows: next we provide a review of how quantity has been incorporated into experimental auctions to date, a discussion of potential mechanisms through which quantity may influence WTP, and study hypotheses. Section 3 outlines the experimental design, study design, data, and empirical strategy. Results and a discussion of implications for seed companies are presented in Section 4 while Section 5 concludes.

2. Background and Potential Mechanisms

2.1 Quantity in Experimental Auctions

Most experimental auction research incorporating quantity has involved multi-unit homogeneous consumer goods to test the theories of demand reduction and diminishing marginal utility to ensure incentive compatibility across different auction mechanisms (Lusk and Shogren, 2007; Canavari et al., 2019).[20] List and Lucking-Reiley (2002) studied the effects of demand reduction in baseball cards by comparing uniform-price and Vickrey sealed-bid auction outcomes. Ausubel (2004) tested ascending-bid auctions for multi-unit homogeneous goods, communications licenses, where the auctioneer announced a price and bidders responded with their desired quantities, across multiple rounds with price increases. Engelbrecht-Wiggans et al. (2006) found that demand reduction decreased as the number of bidders increased. Such studies helped formulate experimental auction best practices, such as selecting a binding round and/or product when multiple rounds or product units are used (regardless of homogeneity) (Lusk and Shogren, 2007).

Only recently has there been an interest in researching the experimental quantity being valued. Instead of using the typical small quantity in their experimental design, Maredia and Bartle (2022) ask Kenyan farmers to bid on a 50-kg bag of potato seed, the modal size that farmers purchase. They do this to obtain a more accurate valuation, as farmers are more familiar with thinking about potato seed prices at this quantity. However, Maredia and Bartle (2022), cap the quantity that can be purchased at 5kgs for logistical reasons.[21] We extend this approach by

[20] Demand reduction refers to a decrease in demand as the price increases.
[21] Unlike, Maredia and Bartle (2022), we do not restrict (cap) the binding seed quantity in the experiment that can be purchased, better reflecting a market environment.

allowing both the price and experimental quantity to vary across farmers with the idea that farmers match their bid quantity to their intended purchase quantity.

2.2 Mental Budgeting

Mental budgeting is a possible mechanism related to the underlying effect of experimental quantity on WTP estimates (Lin et al. 2022). Thaler (1999) defines mental budgeting as cognitive operations used to organize, evaluate, and keep track of financial activities. Practically, individuals group their expenditures or income into ‘mental accounts’ from which ‘mental budgets’ are adopted (Thaler, 1999). Because budgets are imperfect in anticipating all consumption opportunities in a period, individuals often earmark either too little or too much money for a particular good. However, evidence shows that the effects of mental budgeting are larger for purchases that are highly typical of one’s past or allocated purchases (Heath and Soll, 1996) meaning in our context that budgeting effects will be most accurate when respondents’ purchase quantity is equal to the experimental quantity for which they are bidding.

Further, individuals often make a purchase if the costs fall within the ‘mental budget’ where cost is reliant upon price and quantity (Thaler and Shefrin, 1981). Therefore, when a respondent is bidding on a small quantity, it likely fits into their ‘mental budget’ while the same may not be true for larger quantities (Lin et al., 2022). This can lead to a potential bias in WTP from mental budgeting if the experimental quantity base is significantly different than the quantity the respondent is using in their mental accounts based on past or allocated purchase categories/amounts. In this case, Lin et al. (2022) found such that one over-states per-unit WTP for small quantities when compared to per-unit WTP when the question is framed with a larger quantity base. Essentially, this leverages the idea that mental budgeting becomes a less precise heuristic in stating WTP when the experimental quantity (and corresponding total budget) is greatly different than respondents' commonly purchased or intended purchase quantity (and corresponding total budget). We further explore this concept by allowing respondents in the VQG to specify the quantity they desire to purchase as the experimental quantity, which likely falls within their mental budget, eliminating any potential bias.

It is possible other mechanisms, beyond mental budgeting, could impact results. Specifically, bulk discounting could exist for large quantity seed purchases such that farmers with greater input requirements negotiate a lower per-unit price (Rawlikowska et al., 2017). Though there is no bulk discount offered by the seed company we worked with, it does not mean farmers are not bidding as such.

2.3 Hypotheses

Producers typically purchase large quantities of seed so it is expected that the mental accounts and budgets from which they formulate their WTP bids will also be large.[22] This typical large quantity purchase and mental accounting is likely significantly different than the fixed, small quantity used in the FQG. Therefore, in this context, it is likely producers will not be as precise when stating WTP bids for smaller quantities. As such, we hypothesize that the average WTP is higher in the FQG compared to the VQG. This is stated as:

$$H_0^1\colon\ WTP_{FQG,2kg} = \ WTP_{VQG,2k-equivalent}$$

$$H_A^1\colon\ WTP_{FQG,2kg} > \ WTP_{VQG,2k-equivalent}$$

Next, let us define the average WTP difference between FQG and VQG bids for each

[22] We note this may not be fully reflective for new seed varieties that a farmer is "trying-out" and, therefore, plants a very small portion of the new seed variety. Research cites that for newly introduced bean cultivars in Uganda, Rwanda, Burundi, and Tanzania, average purchase sizes ranged from 500g for more subsistence-oriented farmers to 1-5kgs for more commercially-oriented smallholder farmers (David and Sperling, 1999). However, as our pre-fixed experimental quantity is 2kgs, we believe this is still within a reasonable quantity range for "trying-out" new varieties. We investigate any WTP biases due to differences in experimental quantity and intended purchase quantity by bean type for hypothesis 2 so, we will isolate the benchmark, known variety and the new, biofortified varieties.

bean seed type j, such that, $Diff_j = WTP_{FQG,2kg,j} - WTP_{VQG,2k-equivalent,j}$. Due to differences in purchase experience, and therefore potential mental budgeting, between seed types, our second hypothesis is that the WTP difference between the FQG and VQG statistically differs by bean seed type. As an individual's mental accounting and budgeting process is likely to be more refined for a commonly purchased good and quantity, we hypothesize that there will be more precision for WTP bids for the benchmark variety than the novel biofortified seed types.

$$H_0^2\!: Diff_{Non-biofortified} = Diff_{Biofortified,no\ label} = Diff_{Biofortified\ with\ label}$$

$$H_A^2\!: Diff_{Non-biofortified} \neq Diff_{Biofortified,\ no\ label} \neq Diff_{Biofortified\ with\ label}$$

3. Methodology

3.1 Experimental Design and Conceptual Framework

To assess the effects of a fixed versus variable experimental quantity in estimating farmers' per-unit WTP, this study uses a between-subjects design with two treatment groups. Study participants are randomly assigned to either a FQG or a VQG. The VQG treatment is designed to align farmers' WTP bids with their intended purchase quantity and thus eliminate any bias that come from mental budgeting. In the experiment, the predetermined fixed quantity is 2 kilograms of seed, the smallest pack size available in the market (Gwaze, 2022). We obtain the VQG WTP by first asking farmers the quantity of seed they are interested in purchasing followed by the corresponding total amount they are willing to pay for the specified seed quantity. The total amount a farmer is willing to pay is then converted to a 2-kg price and compared to the WTP for 2kg seed in the FQG.

To carry out our experiment, we utilize the Becker-DeGroot-Marschark (BDM) mechanism (Becker, DeGroot, & Marschak, 1964), an incentive-compatible, non-hypothetical procedure commonly used in experimental economics to measure WTP (Lusk and Shogren, 2007; Cole et al., 2020). In BDM, respondents submit a bid that is compared against a randomly drawn price from an *ex-ante* established market price distribution. In the case of individuals bidding on multiple goods, one good is selected at random to avoid demand reduction effects. If the respondent's bid for the randomly selected good is greater than or equal to the randomly drawn market price, then they pay the randomly drawn price and receive the good; otherwise, no transaction occurs.

The main benefit of using the BDM mechanism is that it allows for a quasi-market scenario that can be carried out with only one respondent present because the price is determined exogenously. We elected to use this method for eliciting WTP as this experiment was part of a larger farmer survey which took place in or near each farmer's house with only the enumerator present. Further, in the case of the VQG, conducting this study with a BDM mechanism ensured that each farmer was able to provide their specific desired purchase quantity. The BDM has drawbacks, mainly that it can be difficult to understand compared to other experimental auctions (Cason and Plott, 2014). To overcome this, we conducted a practice round and addressed respondents' questions before conducting the experiment.

3.2 Study Design

This experiment was part of a nationally-representative bean adoption study of 1,521 households.[23] From the total number of households, a sub-sample of 527 households was randomly selected to participate in the WTP experiment, split evenly between the two treatment groups.[24] Treatment group assignments were randomized at the village level to limit potential conflict if neighbors had the opportunity to bid on different seed quantities. In the experiment,

[23] For details on how the sampling was conducted for the adoption study, please see Appendix A1.
[24] Based on sampling calculations of allowing a Type I error of 5% and a Type II error of 20%, and a treatment effect size over standard deviation of one-fourth, the needed between-subjects sample-size is 251 individuals per treatment group (Lusk and Shogren, 2007; Canavari et al., 2019).

farmers submitted bids for three bean seed types in three rounds, with incremental information given in subsequent rounds (see Appendix A3 for details).[25] In the FQG, at the end of the experiment but before any binding round/product or random price were selected, farmers were asked about the quantity of seed they would purchase for each seed type at their stated price in round 3. This is considered their intended purchase quantity, which was outside the experiment's framing and non-binding. To make the intended purchase quantity comparable across FQG and VQG, we focus our analysis on third round bids.[26] Respondents were told that only one round and one product would be selected as binding following the experiment, according to standard BDM procedures when there are multiple products and/or rounds. In each experimental group, respondents were asked to bid for three bean products based on information presented on the 2kg seed packs available for them to observe and any information shared by the enumerator. The specific information on the seed packs is presented in Table 3.1; pictures of the seed packs are available in the Appendix A.2.

Table 3.1: Seed pack information by product

Information Type	Product 1	Product 2	Product 3
Variety Name	Gloria	NUA45	NUA45
Company	ARDA	ARDA	ARDA
Size of Seed pack	2kg	2kg	2kg
Color of seed	Cream	Purple-mottled	Purple-mottled
Biofortified *(credence attribute)*	No	Yes	Yes
Additional Label	No	No	Iron and Zinc Enriched

Prior to conducting the experiment, enumerators explained the BDM procedure and conducted a practice round. The practice round was comprised of three different matchboxes, a

[25] Respondents' bid price in both treatment groups, and quantity in the VQG, was not based on any previous round answers – every price and/or bid quantity could be updated after each round for each seed product.
[26] Analysis of the incremental impact of information on farmer WTP for each of the three bean seed types is conducted in a different study.

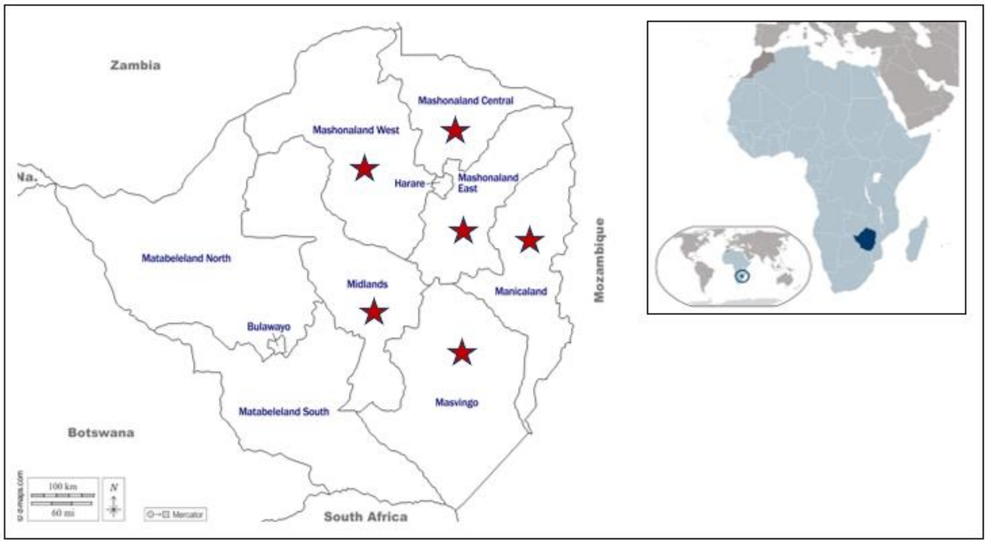
common non-focal product in rural Zimbabwe with known market prices. To ensure familiarity with the elicitation mechanism, farmers were encouraged to ask any clarifying questions regarding the BDM procedure.

Currently, Zimbabwe has a multiple currency system, the US dollar (USD) and the local Zimbabwean dollar, officially the Real Time Gross Settlement dollar (RTGS dollar), which was reintroduced in 2019. We use USD in this study as most people prefer this currency due to RTGS' hyperinflation. The *ex-ante* established uniform price distribution used in the FQG experiment for 2kg bean seed packs was $0-14 USD, in increments of $1 USD. This was based on the average market price of bean seed, which was $7.00 for a 2kg pack. For the VQG, the underlying price distribution was $0-7 USD per 1kg of seed as we converted each respondent's bid to a 1kg-equivalent price for ease in selecting the 'market price'. This price was then scaled by the appropriate quantity to determine the total amount to be paid for the quantity of seed for which they bid. Respondents were not told the price distribution but instructed to think of typical bean seed market prices. We did not reveal the price distribution as past studies have found that BDM may not be incentive-compatible in such cases as respondents' bids may depend on the price distribution (Horowitz, 2006; Ortega and Wolf, 2018). Our study was conducted prior to planting, which ensured farmers were assessing market prices.[27] Respondents' bids were not censored in either group (e.g., farmers could bid any amount) and the quantity stated by VQG farmers was also uncensored but constrained to 1kg increments, reflecting an actual market scenario.

This experiment was carried out between November and December 2022 throughout the six bean-producing provinces of Zimbabwe, as shown in Figure 3.1.

[27] We control for farmers that had already purchased any quantity of bean seed prior to the experiment in regression analysis as outlined in Section 3.4.

Figure 3.1: Provinces where bean WTP experiments were conducted



Source: mapsland.com and d-maps.com with author additions
Note: Provinces where experiment took place are marked with red stars

Farmers received neither an endowment for purchasing seed nor a participation gift. Therefore, farmers submitted bids based on the money they had with them the day of the survey. Farmers were informed by their village leaders to come prepared to potentially purchase product the day of the experiment. As there was no endowment from which to automatically deduct payment if a household had the opportunity to engage in a transaction, some households refused to pay. Sixteen percent of FQG respondents had the opportunity to purchase a specific 2kg seed pack but refused, while the rate was 13% in the VQG, though there is no statistical difference. We control for this refusal behavior in the analysis.

3.3 Data

Approximately 70% of respondents were their household's head, 45% were female, were on average 50 years old, and the majority had completed secondary school. On average, a household size was comprised of five individuals. Respondents cultivated approximately 3.4 hectares of land in the last season, of which 0.45 hectares was sown to beans. Our sample is generally balanced across treatment group (Table 3.2). Only four of 23 variables are significantly different at or below the 10% level: the percentage of respondents that are the household head, the percentage female respondents, household size, and farming being the main source of employment. As such, we include these as control variables in our analysis.

Table 3.2: Bean sample demographic and agricultural characteristics and balance tests

	Fixed Quantity Group (n=262)		Variable Quantity Group (n=265)		Test of equal means: FQG=VQG
Variable	Mean	Std. Dev.	Mean	Std. Dev.	p-value
Respondent is household head (HH) (%)	76.72	(42.34)	67.17	(47.05)	0.0147
Respondent is female (%)	41.60	(49.38)	49.06	(50.01)	0.0860
Respondent's age	51.24	(14.25)	50.23	(13.76)	0.4063
Respondent completed secondary school (%)	56.49	(49.67)	61.51	(48.74)	0.2421
Respondent's main source of employment: own farming (%)	87.89	(32.81)	92.45	(26.47)	0.0727
Household Size	4.78	(2.01)	5.36	(2.62)	0.0044
Agricultural					
Total land area cultivated last season (ha)	3.60	(9.97)	3.34	(2.26)	0.7038
Total bean land area cultivated (ha) last season	0.50	(1.45)	0.38	(0.38)	0.2306
Quantity (kgs) bean seed planted last season	27.16	(26.45)	23.58	(29.94)	0.1444
Purchased bean seed last season from agrodealer (%)	22.90	(42.10)	21.89	(41.43)	0.7806
Average price/kg (USD) paid for bean seed purchased last season	2.53	(2.30)	2.54	(1.47)	0.9938
Average bean varieties grown last season [a]	1.13	(0.50)	1.11	(0.40)	0.6709
Respondent grew an improved bean variety last season (%) [a,b]	68.08	(0.47)	71.83	(0.45)	0.3991
Respondent grew Gloria last season [a]	50.70	(50.11)	48.36	(50.09)	0.6290
Respondent grew NUA45 last season [a]	34.27	(47.57)	38.97	(48.88)	0.3157
Of those that grew Gloria, respondent purchased seed from agro-dealer (%)	21.30	(41.13)	23.30	(42.48)	0.7280
Of those that grew NUA45, respondent purchased seed from agro-dealer (%)	17.81	(38.52)	19.27	(39.69)	0.8154
Bean listed among top two most important crops grown for HH consumption (%)	64.89	(47.82)	60.75	(48.92)	0.3275
Bean listed among top two most important crops grown for HH income source (%)	59.54	(49.18)	53.96	(49.94)	0.1968
Already purchased some bean seed for planting (%)	11.07	(31.43)	11.70	(32.20)	0.8205
Has received or expects to receive bean seed from the government (%)	12.21	(32.81)	14.72	(35.50)	0.4010

Test of equal means across group assignment is an F-test of equality across groups.
[a] Not all households in the experiment grew beans last year so the comparison for 'last season' is FQG=213, VQG n=213.
[b] Farmers self-identified if the variety(ies) they grew were improved.

3.4 Empirical Strategy

Regression analysis of farmer WTP is estimated using pooled Ordinary Least Squares estimation.[28] We begin with a parsimonious model specification in Equation 1. Our key coefficient of interest for hypothesis one is β, the FQG average WTP for 2kg bids for the seed products compared to the base case, the VQG average WTP for 2kg-equivalent of seed submitted, pooling across the three bean seed types. In Equation 2, we add a vector of farmer-level control variables ($\boldsymbol{X_i}$). Equation 3 explores the effects of mental budgeting. Specifically, we incorporate dummy variables representing if a respondents' intended purchase quantity (IPQ) is less than 2kgs or greater than 2kgs and an interaction term of treatment group assignment with these two intended purchase quantity variables. Finally, in equation 4, we augment equation 3 with farmer-level control variables.

$$Bid_{it} = \alpha + \beta T_t + u_{\boldsymbol{it}} \quad (1)$$

$$Bid_{it} = \alpha + \beta T_t + \boldsymbol{\eta X_i} + u_{\boldsymbol{it}} \quad (2)$$

$$Bid_{it} = \alpha + \beta T_t + \mu IPQBelow_i + \pi IPQAbove_i + \delta(T_t \, x \, IPQBelow_i) + \gamma(T_t \, x \, IPQAbove_i) + u_{it} \quad (3)$$

$$Bid_{it} = \alpha + \beta T_t + \mu IPQBelow_i + \pi IPQAbove_i + \delta(T_t \, x \, IPQBelow_i) + \gamma(T_t \, x \, IPQAbove_i) + \boldsymbol{\eta X_i} + u_{it} \quad (4)$$

Where Bid_{it} is the WTP bid for farmer *i* in treatment group *t*. Variable T_t delineates the treatment groups where t=1 for the FQG while *t*=0 represents the VQG, which serves as the base group. The $\boldsymbol{X_i}$ represents a vector of respondent characteristics and experiment controls. Respondent control variables include respondent age, if the respondent was the household head (0/1), if the respondent was female (0/1), if the respondent's education achieved was above primary level (0/1), household size, the respondent's asset quartile (ranging from 1-4; details on

[28] There are less than 5% (1.8%) zero bids, resulting in estimates between Tobit and OLS not diverging in a meaningful way (Canavari et al., 2019).

how the asset index was created are in Appendix A.4), and district. Additional covariates are whether the respondent had already purchased any bean seed (0/1), if the respondent had received or expected to receive free bean seed from the government (0/1), experiment outcome dummy variables: if the respondent had the opportunity to purchase seed and refused (0/1) and if the respondent did not have the opportunity to purchase seed (0/1). Respondents that had the opportunity to purchase seed and paid for it are the omitted group. We also control for the unbalanced variables noted in Section 3.3. Further, we include the dummy variables comparing intended purchase quantity (IPQ) to the experimental quantity of 2kgs: 'IPQBelow' and 'IPQAbove'. IPQ equal to 2kgs is omitted for identification purposes and serves as the base group. Finally, u_{it} is the idiosyncratic error term. As each farmer submitted three bids, one for each bean seed type, we cluster our robust standard errors at the farmer level.

We explore heterogeneity effects of the difference in FQG and VQG WTP bids by bean seed type to address hypothesis two. This is of particular interest as the mechanism of mental budgeting where one draws on their mental accounts that are informed by past purchases may be different for a known, benchmark variety the respondent has experience purchasing versus a novel product. We also explore differences across bean land size area to assess possible WTP differences in treatment group bids for those who cultivate large versus small land areas, to further investigate the presence of a bulk seed discount by large land area respondents. In addition, we explore heterogeneity effects by respondent gender and wealth status to assess if these variables create differences in mental budgeting. Potentially, men and women use different mental budgeting techniques or those of lower wealth status may be more money-conscious and may not exhibit the effects of the mental budgeting bias compared to higher-wealth respondents. To examine heterogeneity effects across each of the different groups, we estimate equations 2 and 4 noted above, separately for each specific bean seed type and for each group - small versus large bean land area, male versus female, and low versus high wealth status.

4. Results and Discussion

4.1 Descriptive Statistics

Mean WTP for FQG and VQG are reported in Table 3.3, along with the corresponding mean intended purchase quantity. There are four key results to highlight. First, WTP for the new biofortified seeds exceed WTP for the benchmark non-biofortified bean seed in both the FQG and VQG. Second, within the biofortified category, seeds with the nutritional label of 'iron and zinc enriched' receive a higher WTP than seeds without the label. Third, when comparing across the two treatment groups, the FQG WTP is 20-61% more than the average 2kg-equivalent VQG WTP, depending on the bean seed type, with $p<0.01$. And fourth, the mean quantity demanded is approximately 12kgs for both the FQG and VQG, approximately six times the FQG experimental quantity (i.e., 2kgs), across all bean seed types.

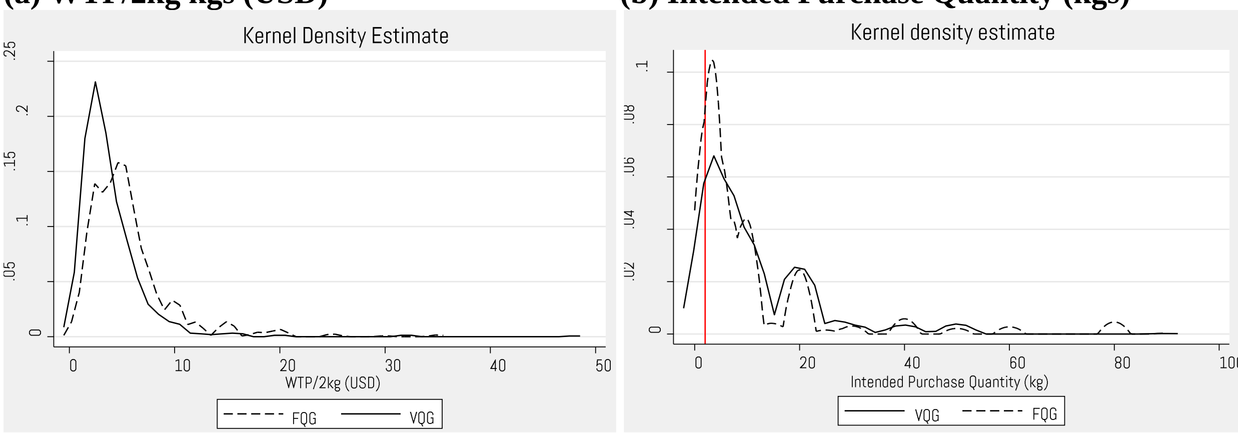
Table 3.3: Total WTP Price (USD/2kg) and Intended Purchase Quantity by Bean Seed Product and Treatment Group

	Mean WTP price (USD/2kg)				Intended Purchase Quantity (kg)		
	FQG	VQG	FQG=VQG P-values		FQG	VQG	FQG=VQG P-values
	(N=262)	(N=265)	F-Tests	K-Tests			F-Tests
					(n=251)	(n=257)	
Non-biofortified	4.13	3.44	0.0047	0.0001	11.17	9.98	0.4207
	(2.77)	(2.84)			(18.41)	(14.72)	
					(n=258)	(n=260)	
Biofortified, no nutrition label	5.69	3.77	0.0000	0.0001	12.24	11.34	0.6789
	(3.93)	(3.05)			(19.26)	(12.55)	
					(n=259)	(n=264)	
Biofortified with nutrition label	6.94	4.30	0.0000	0.0001	13.3	15.48	0.2309
	(4.67)	(3.96)			(19.81)	(21.76)	
Overall	5.59	3.83	0.0000	0.0001	12.24	12.29	0.9592
	(4.03)	(3.33)			(19.17)	(16.99)	

Note: standard deviations are in parenthesis. F-tests come from the parametric equality of means tests while K-tests come from the non-parametric Kruskal-Wallis rank test. We only include respondents whose intended purchase quantity was positive so we depart from the full sample.

The WTP distribution across all bean seed types by treatment group is shown in Figure 3.2 (panel a). The FQG has a higher WTP but a smaller range than the VQG. Further, most farmers intended to purchase more than 2kgs of bean seed (72% and 79% of FQG and VQG, respectively), (panel b).[29]

Figure 3.2: Bean Kernal Density Estimate by Treatment Group
(a) WTP/2kg kgs (USD) **(b) Intended Purchase Quantity (kgs)**



Note: the red vertical line in panel b represents 2kgs.

Within each treatment group, we partition respondents into three categories according to their intended purchase quantity (IPQ) for each bean type: less than 2kgs of bean seed, equal to 2kgs, and more than 2kgs (Table 3.4). We use these categories and compare against 2kgs, the experimental quantity used in the FQG, to assess potential differences in WTP due either to mental budgeting or bulk discounts. If the difference in FQG and VQG WTP is due to bulk discounts, we expect there to be a significant difference within the VQG across the difference IPQs with average WTP in the IPQ>2kgs group being significantly less than the other IPQ

[29] Note, we include average per-unit WTP for respondents' intended purchase quantity by treatment group in Appendix A.5. After 2kgs, the FQG per-unit value is higher than, or equal to, the VQG per-unit value for each intended purchase quantity except one (50kgs and above).

groups. If the FQG and VQG WTP difference is driven by a bias due to mental budgeting (as the experimental quantity is different than the IPQ), we would expect there to be a significant difference within the FQG group with WTP in the IPQ<2kgs group being less than the IPQ=2kgs group while the IPQ>2kgs group average WTP would be greater than the IPQ=2kgs group.

The average WTP across the FQG's intended purchase categories is statistically different ($P<0.01$), where the average WTP for the individuals who intended to purchase greater than 2kgs having a much higher WTP than the other two IPQ groups. The VQG is the proposed experimental method which eliminates mental budgeting by design, and as such, no significant difference should exist in average WTP across the three intended purchase quantity categories. If any difference does exist, it should be due to respondent characteristics. We find no significant difference within the VQG (p-value: 0.2243). Comparing across treatment groups and within the same IPQ categories, a significant difference ($p<0.01$) exists for those who intended to purchase more than 2kgs of seed but in no other IPQ category. The descriptive results point to an upward bias in the FQG which is consistent with a bias resulting from mental budgeting. However, the mean comparison across the treatment group may be confounded by respondent characteristics. To account for these confounding factors and to formally test the hypotheses, we turn to econometric analyses.

Table 3.4: Average WTP conditional on comparison of experimental quantity to Intended Purchase Quantity (IPQ) across all bean seed types

	Less than 2kgs *(Group 1)* IPQ < 2kgs (FQG n=13, VQG n=5)	Equal to 2kgs *(Group 2)* IPQ = 2kgs (FQG n=206, VQG n=157)	More than 2kgs *(Group 3)* IPQ > 2kgs (FQG n=549, VQG n=623)	Equality of means p-value *Groups 1=2=3*
FQG (n=768)	4.05 (2.41)	4.41 (3.22)	5.96 (3.85)	0.0000
VQG (n=785)	4.20 (1.79)	4.29 (2.54)	3.78 (3.50)	0.2243
Equality of means p-value *(FQG=VQG)*	0.8933	0.6988	0.000	---

Note: We only consider instances of someone having a positive intended purchase quantity, so we depart from the full sample size of FQG: n=786 and VQG: n=795.

4.2 Main Model Results

There are five key results from the econometric analyses to assess the impact of experimental quantity on per-unit WTP and the potential presence of a bias from mental budgeting or bulk discounting (Table 3.5). First, on average, when pooling bids across bean seed types and intended purchase quantities, farmers randomly assigned to the FQG bid $1.64 more (a 42% bias) for 2kgs of seed than those in the VQG (p<0.01) (Table 5). We consider the VQG WTP to be the respondent's true WTP as it is based on their stated quantity preferences. Therefore, our findings support our first hypothesis that bid experimental quantity impacts per-unit WTP.

Second, to assess if the difference in experimental and intended purchase quantity is driving the FQG bias, we incorporate the intended purchase quantity variables in models 3 and 4. Once these variables are included, the coefficient of the FQG treatment variable is no longer significantly different than zero when compared to the base (VQG), where both groups represent respondents whose intended purchase quantity is equal to 2kgs. This result is not surprising given that in both FQG and VQGs respondents' intended purchase quantity equaled the experimental quantity and therefore, the quantity bid for is the same in both groups (i.e., 2kgs). Third, within the VQG, the average bid is not significant compared to the base constant (VQG respondents that bid for 2kgs) for respondents that bid for less than 2kgs or greater than 2kgs. This result indicates that the experimental design adequately incorporates mental budgeting and further, that the mechanism of bulk discounting and diminishing marginal WTP is not supported by the data. Fourth, the FQG variable for respondents whose intended purchase quantity was more than 2kgs were willing to pay an additional \$2.18 ($p<0.01$) compared to those in the FQG whose IPQ equaled 2kgs. The significance of this variable suggests that either respondents are characteristically different across these two IPQ categories or there is a bias due to mental budgeting (the divergence in intended purchase quantity and experimental quantity). Since we control for respondent characteristics (model 4), this result is supportive of the presence of the overestimation bias that can arise due to mental budgeting when intended purchase quantity is greater than the experimental quantity. Fifth, likely due to small sample size, WTP for the respondents whose IPQ was less than 2kgs was not significant compared to the base category within the FQG. Therefore, econometric results suggests that difference in average WTP between the FQG and VQG is driven by respondents in the FQG whose intended purchase quantity is greater than the experimental quantity used of 2kgs, which is consistent with the bias that can arise from mental budgeting.

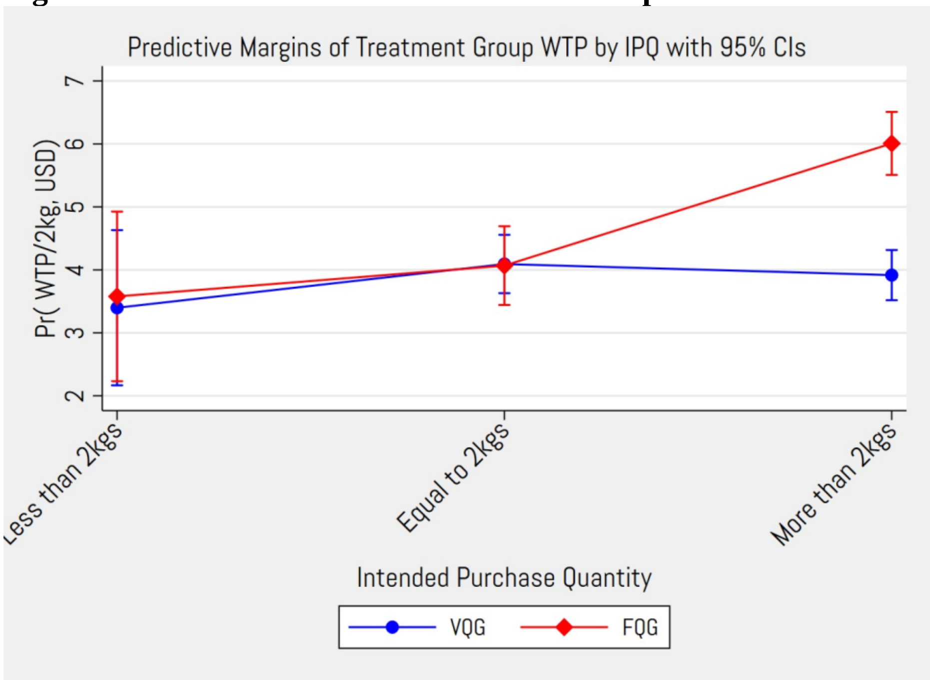
Table 3.5: Estimation Results for WTP (USD) for 2kgs of Bean Seed by Treatment Group

	Model 1			Model 2			Model 3			Model 4		
Variables	Coef.	Robust SE		Coef.	Robust SE		Coef.	Robust SE		Coef.	Robust SE	
Constant	3.87	0.19	***	3.07	1.58	*	4.12	0.22	***	3.16	1.59	**
Treatment Group (Base=VQG)												
Fixed Quantity Group (0/1)	1.64	0.28	***	1.55	0.32	***	0.07	0.38		-0.025	0.41	
Intended Purchase Qty (IPQ), (Base: Intended Qty=2kg)												
IPQ < 2kg	--			--			-0.70	0.62		-0.69	0.93	
IPQ > 2kg	--			--			-0.30	0.19		-0.18	0.19	
Interaction terms												
FQG x IPQ < 2kg	--			--			0.14	0.91		0.20	0.93	
FQG x IPQ > 2kg	--			--			2.18	0.43	***	2.12	0.43	***
Respondent Controls Included	No			Yes			No			Yes		
Post-estimation equality tests p-values:												
FQG=VQG: Equals 2kgs	--			--			0.8590			0.952		
FQG=VQG: IPQ<2kgs	--			--			0.8764			0.8248		
FQG=VQG: IPQ>2kgs	--			--			0.0000			0.0000		
Number of Observations	1553			1553			1553			1553		
Number of Clusters (Households)	526			526			526			526		
R-Squared	0.0511			0.1573			0.0712			0.1750		

** = p <0.10, ** = p <0.05, *** = p <0.01; Note: Results are averaged across all bean seed types. Full estimation results are in A.6.1A.*

As seen in econometric results, there is no significant difference between the FQG and VQG average WTP across all bean seed types when intended purchase quantity is less than 2kgs (Figure 3.3). There is also no difference across treatment groups when intended purchase quantity equals 2kgs of bean seed. However, there is a difference ($p<0.01$), which is visually apparent, between the FQG and VQG average WTP for the respondents whose intended purchase quantity is greater than 2kgs of seed.

Figure 3.3: Total WTP across Treatment Groups and Intended Purchase Quantity (IPQ)



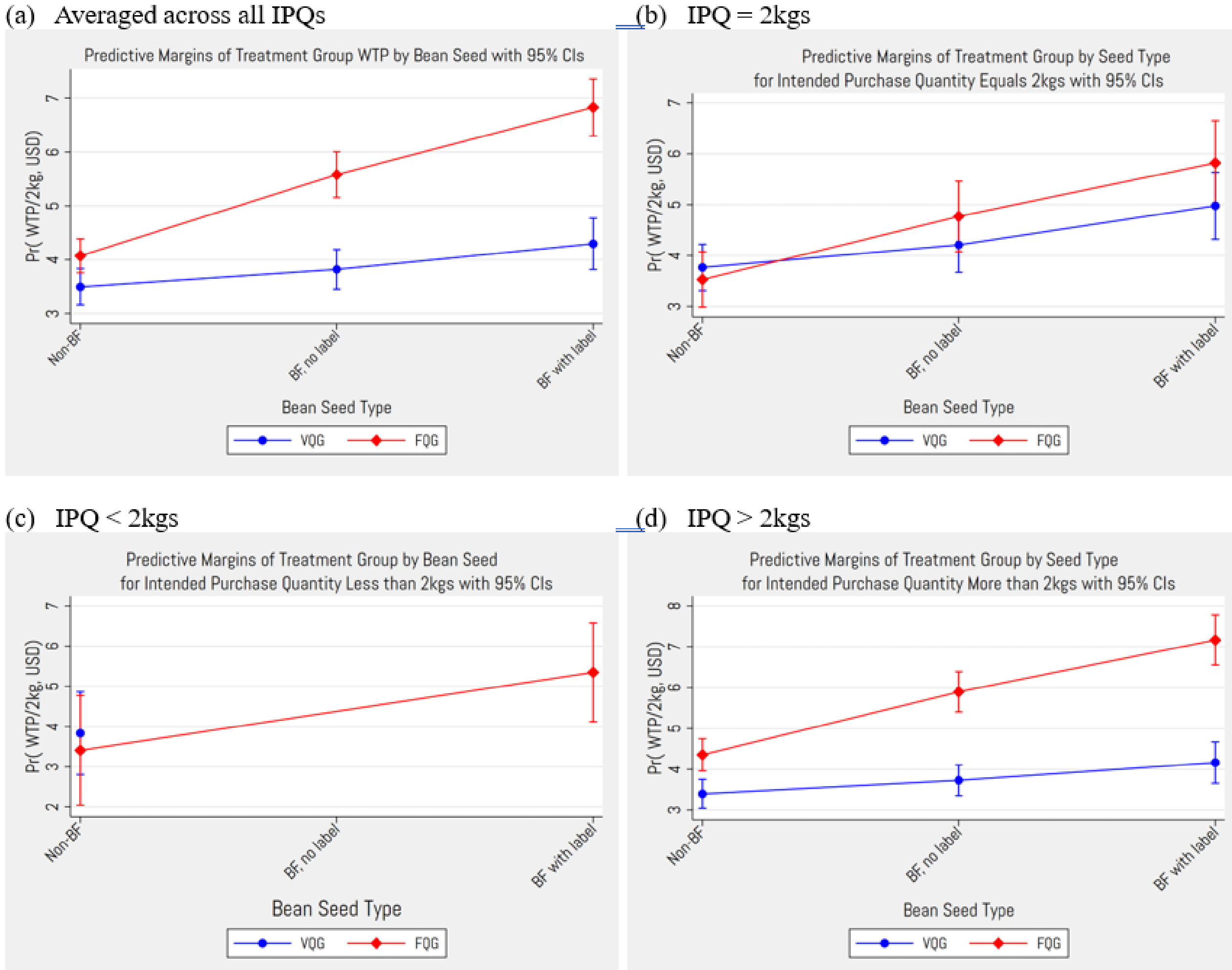
4.3 Heterogeneous Effects

When formulating bids, individuals draw on mental accounts where the bid precision can be informed by past purchase experiences, the size of the budget, or differences in respondent characteristics. Therefore, we explore if differences exist in treatment group effects (FQG versus VQG average bids) according to bean seed type, bean land area cultivated, respondent gender and wealth status. We specifically look at bean type as we believe that mental accounting can differ in its precision, due to purchasing experience, for the commonly purchased benchmark variety compared to the novel biofortified. For instances where differences in the FQG bias exist, we assess the extent to which mental budgeting can explain the bias. Specifically, we determine if the effects of overestimation of WTP in the FQG versus the VQG are stable or if they are influenced by product type or respondent characteristics. We find no heterogeneous effects across bean land size, respondent gender or wealth (Appendix A.6.3, Tables A.6.3A, A.6.3B). Therefore, we focus only on bean seed type given results, which are indicative of heterogeneous effects.

Bean Seed Type

Pooling across all intended purchase quantities, the difference in FQG and VQG WTP increases as bean seed type becomes more differentiated (Figure 3.4, plot a). Figure 3.4, plot a results draw on econometric regression estimations of bean seed type and treatment group interactions regressed on average WTP for bean seed (Table 1 in Appendix A.6.1). The intended purchase quantity category that explains this difference is the ‘more than 2kgs’ group (plot d). There is a significant difference in average WTP between the FQG and the VQG with the average distance becoming greater as the bean seed type becomes more differentiated/specialized. There is no significant difference in WTP by treatment group when intended purchase quantity equals 2kgs or is less than 2kgs (plots b and c). Figure 3.4, plot b-d draw upon econometric results of Table 2 in Appendix A.6.2 which is a fully saturated model of bean seed type, intended purchase quantity, and treatment groups interacted.

Figure 3.4: Total WTP for Bean Type by Treatment Groups and Intended Purchase Quantity (IPQ) Categories



*Note: there were no observations for IPQ<2kgs for the BF, no label seed type in either treatment group, and no observations for IPQ<2kgs for the BF, with label seed in the VQG group.

Empirically, we find heterogeneous effects in the FQG bias across bean seed type. FQG farmers are willing to pay an additional $0.69 (22% more) compared to the VQG for the benchmark bean seed, the non-biofortified variety (Table 3.6). The bias is largest for the biofortified bean types with farmers willing to pay an additional $1.70 (a bias of 65%) compared to the VQG for the biofortified bean seed without the nutrition label and an additional $2.67 (a bias of 64%) than the VQG group for the biofortified bean seed with the nutrition label. These biases are statistically different from one another, (p<0.01) in every combination. For those in the FQG that intended to purchase a quantity greater than 2kgs, the coefficient is large and significant (p<0.01) for each bean seed type (Table 3.6: $1.37, $1.63. and $2.21, respectively).

The ‘FQG’ variable coefficient is not statistically different from zero when intended purchase quantity equals 2kgs; nor is the FQG variable coefficient for respondents whose intended purchase quantity was less than 2kgs. The coefficient on the ‘FQG x IPQ > 2kgs’ variable is significantly different (p<0.10) between the non-biofortified seed ($1.37) and the biofortified seed with the nutrition label ($2.21) but there is no significant difference between the ‘FQG x IPQ > 2kgs’ coefficients of two biofortified seed types ($1.63 and $2.21), or between the non-biofortified and biofortified with no nutrition label ($1.37 and $1.63, respectively). We suggest that this difference in the FQG bias across seed types is the result of mental budgeting based on respondents’ having more (less) experience purchasing non-biofortified beans compared to the new biofortified variety.

Table 3.6: WTP/2kg Of Seed by Treatment Group and Intended Purchase Quantity (IPQ) for Each Bean Seed Type

	M1: Non-biofortified Bean			M2: Non-biofortified Bean			M1: Biofortified Bean without nutrition label			M2: Biofortified Bean without nutrition label			M1: Biofortified Bean with nutrition label			M2: Biofortified Bean with nutrition label		
Variables	Coef.	SE		Coef.	SE		Coef.	SE		Coef.	SE		Coef.	SE		Coef.	SE	
Constant	3.16	1.25	**	3.29	1.31	**	2.63	1.62		2.63	1.63		3.57	2.22		3.93	2.19	
Treatment Group (Base=VQG)																		
Fixed Quantity Group	0.69	0.26	**	-0.34	0.40		1.70	0.37	***	0.48	0.54		2.28	0.45	***	0.50	0.77	
IPQ (Base: =2kg)																		
IPQ <2kgs	--			-0.35	1.17		--			--			--			--		
IPQ > 2kgs	--			-0.16	0.36		--			-0.15	0.42		--			-0.58	0.60	
Interaction terms																		
FQG x IPQ < 2kgs	--			0.69	1.25		--			--			--			0.62	1.48	
FQG x IPQ > 2kgs	--			1.37	0.49	***	--			1.63	0.63	***	--			2.21	0.86	***
Respondent Controls Included	Yes			Yes			Yes			Yes			Yes			Yes		
Number of Observations	509			509			519			519			524			524		
R-Squared	0.1708			0.1893			0.1723			0.1885			0.2103			0.2217		

* = p <0.10, ** = p <0.05, *** = p <0.01; IPQ = Intended Purchase Qty; SE=robust standard error. Full estimation results are in A.6.1B.

Note 1: there were no FQG respondents had IPQ< 2kgs for the biofortified bean without the nutrition label. Similarly, there were no VQG respondents that had an IPQ< 2kgs for the biofortified bean without or with the nutrition label.

Note 2: Model 1 post-estimation tests: There is a significant difference (p<0.01) for the FQG Non-biofortified bean coefficient compared to the FQG Biofortified bean, no label coefficient, for the FQG Non-biofortified bean coefficient compared to the FQG Biofortified bean, with the label coefficient, and between the two biofortified seed types. Model 2 post-estimation tests: There is a significant difference (p<0.10) between the coefficients of FQG x IPQ>2kgs for the non-biofortified bean and the biofortified bean type with the nutrition label. No significant difference in coefficients exists between the FQG x IPQ>2kgs for the non-biofortified bean and the biofortified bean with no label, nor between the two biofortified seed types.

4.4 Implications for Seed Demand Estimation

Zimbabwe seed companies, NGOs, and the government have a profound need for unbiased WTP estimates for the biofortified seeds they distribute. Seed companies need WTP estimates to correctly set profit-maximizing prices and estimate demand and market size at such prices. For NGOs and the government, WTP estimates are needed to estimate potential farmer uptake and create any policy/programmatic lever to bridge the gap between farmers' WTP and the market price (i.e., seed companies' willingness to sell price). As seen in this study, WTP results are sensitive to the experimental quantity used in the elicitation procedure. While the resulting difference in WTP may seem trivial (e.g., an extra WTP of $0.50 or $1.00), it is not trivial to a seed company formulating their pricing strategy and market demand estimates for large scale sales or NGOs/government creating potential input price support measures.

To illustrate this point, we calculate effective demand for a hypothetical seed company in Table 3.7. Currently, the market price for both the non-biofortified seed and the biofortified seed with no nutrition label is $7 per 2kgs of seed. The biofortified bean seed with the nutrition label is not currently on the market but we use the same $7 per 2kg price for the biofortified seed available in the market as the varieties are identical. The percentage of respondents willing to pay at or above the market price of $7 is not significantly different between the treatment groups for the benchmark bean seed but is for the two biofortified seed types (38% of FQG respondents versus 12.5% of VQG respondents for the biofortified labeled seed). Based on this experiment's sample size, the predicted seed demand between the two treatment groups diverges as the bean types become more differentiated. For the biofortified labeled seed, the FQG predicted demand is approximately 1,220 kgs while the VQG predicted demand is 440 kgs, a difference of 780 kgs of seed or 63.9%.

Further, the difference in farmers' average WTP/2kgs for biofortified seeds of $6.94 (FQG) versus $4.30 (VQG) has major implications when designing any price support scheme to increase farmer uptake of biofortified seeds. First, the price differential between farmers' WTP and the market price of $7/2kg seed pack ranges between $0.06-2.70, which has major funding and/or costs implications. Secondly, if the support price is incorrectly set then the target farmer adoption rate of biofortified seed will likely not be achieved, which could have implications for Zimbabwe's efforts to combat iron and zinc deficiency.

Table 3.7: Effective Demand by Treatment Group

	Percent of farmers WTP equal to or above the market price (=$7 USD/ 2kgs)			Number of kgs of bean seed intended to purchase, *conditional on paying at or above the market price*			Total Predicted Demand (kgs) from this experiment's sample size		
	FQG (N=265)	VQG (N=262)	FQG= VQG p-value	FQG	VQG	FQG= VQG p-value	FQG (kgs)	VQG (kgs)	Demand Difference (kgs), (FQG-VQG)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Non-biofortified	12.21 (32.81)	8.30 (27.64)	0.1392	(n=32) 8.69 (9.01)	(n=22) 11.05 (14.1)	0.4563	278.08	243.10	34.98
Biofortified no label	24.04 (42.8)	9.81 (29.8)	0.0000	(n=63) 12.24 (15.68)	(n=26) 14.92 (15.4)	0.4623	771.12	387.92	383.2
Biofortified with label	38.17 (48.67)	12.45 (33.08)	0.0000	(n=100) 12.22 (16.53)	(n=33) 13.42 (16.01)	0.7152	1222	442.86	779.14

Note: Standard deviations are in parentheses.

5. Policy Implications and Conclusions

In this study we conduct an experiment using the BDM mechanism to compare farmer WTP for three types of bean seed. We test the per-unit WTP for bean seed when farmers are randomly allocated to two treatment groups – one where the experimental bid quantity is fixed and small (the Fixed Quantity Group, FQG), and one where farmers' experimental quantity matches their intended purchase quantity (the Variable Quantity Group, VQG). Though classic economic theory suggests that the experimental quantity used in elicitation should not influence per-unit bids and that they are stable across quantities, we find that the FQG WTP is, on average, 42% more than the VQG WTP. This difference can be explained by a bias resulting from mental budgeting. Specifically, when an individual is asked to bid for a quantity that is less than what they plan to purchase, they overbid as they may see the quantity and corresponding expenditure as trivial compared to individuals where the experimental quantity bid on is equal to their intended purchase quantity. Further, we find greater differences in WTP as the bean seed type becomes more differentiated or novel.

The findings of this research contribute to the discussion of best practices in the experimental quantity for preference elicitation methods. To obtain unbiased WTP estimates, our findings suggest researchers set the experimental quantity of the product being bid on equal to a respondent's intended purchase quantity of that good (the VQG). Our results suggest that this is particularly important for novel, highly differentiated agricultural input products. Otherwise, the resulting WTP estimates will likely be biased. Biased WTP bids have more than theoretical implications as they will impact a seed company's ability to accurately set prices for new seeds, estimate market demand, and affect the sustainability of seed products.

The bias that arises from mental budgeting will likely exist for any product when there is a large difference in the experimental quantity and the individuals' intended purchase quantity of said good, such as agricultural inputs (e.g., other crop seed, fertilizer, or pesticides). Further, given the findings of a previous study assessing the impacts of mental budgeting (i.e., Lin et al., 2022) and the findings of this study, we believe the potential bias due to mental budgeting is not limited to a specific country, region, or economic classification of countries.

A limitation of this study is the small sample size of respondents who intended to purchase less than 2kgs of bean seed. This low sample size likely impacted our ability to detect any significant difference in average WTP of this sub-set of respondents between the FQG and the VQG, which would support the presence of an underestimation due to mental budgeting when intended purchase quantity is less than the experimental quantity. Future research could consider using different fixed quantities to test both the under- and over-estimation WTP bias that theoretically can arise due to mental budgeting. Given the limited number of studies that have evaluated the impact of experimental quantity in WTP experiments, future studies in various other contexts, including other agricultural inputs as well as consumer goods, in developing and developed countries are needed.

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APPENDIX

A.1 Sampling for the Nationally-Representative Bean Study

This study leans on the sampling design of the nationally-representative bean farmer adoption survey of which this study was a part. We first obtained a sampling frame from the AGRITEX (Zimbabwe Agricultural and Extension Department) office of the land allocated to beans at the ward level within each province in the last growing season. In the first stage, wards were randomly selected among the provinces, conditional on the ward having a minimum of 45 hectares of bean land area. The number of wards randomly selected within each province was proportional to bean land area size of the province as a percentage of total bean land area in the country. In stage 2, villages per ward were randomly selected. Survey team leads communicated with the local district AGRITEX officer for the villages randomly selected to be enumerated as well as local government officials. Once the enumerator team arrived in each village, they first took a day, or two, if necessary, to list all bean growing households. Following this, 12 households and six replacement households were randomly selected to be interviewed for the main survey. The bean experiment carried out in this study was only implemented on a sub-sample of the main adoption survey respondents. To select the specific villages where the experiment was to be carried out, we randomly selected villages stratified by provinces.

A.2 Pictures of Bean Seed Samples

Figure A.2 below shows the three bean seed packs that were used in the survey for respondents evaluate when giving their WTP.

Figure A.2: Bean Seed Packs used in Experiment

A.3 Scripts

<u>**Round 1:**</u> respondents observe the seed packs, as shown in A1.

<u>**Round 2:**</u> ***Enumerator read:*** Iron deficiency is a severe public health issue in Zimbabwe as approximately 7 out of 10 children and 6 out of 10 women of reproductive age suffer from iron deficiency. Iron deficiency can impair the mental development and learning capacity of children, increase weakness and fatigue, and increases the risk of childbirth complications for the baby and mother. Further, zinc deficiency is also a severe public health concern in Zimbabwe as 1 in 2 individuals are at risk of inadequate zinc intake. Zinc deficiency can impair proper physical growth which can lead to stunting, impair cognitive development, and can cause a weak immune system. Consuming iron and zinc enriched beans can contribute a higher amount of daily iron and zinc needs compared to consuming beans not enriched with these nutrients.

<u>**Round 3:**</u> ***Enumerator read:*** Researchers in Zimbabwe have evaluated the cooking quality of NUA45 beans, the same as the variety presented to you here today. They have found that NUA45 produces a thick soup and the seed swells almost twice their size when cooked. The cooking time for NUA45 grain to become tender, is a little over 1 hour. Compared to other bean

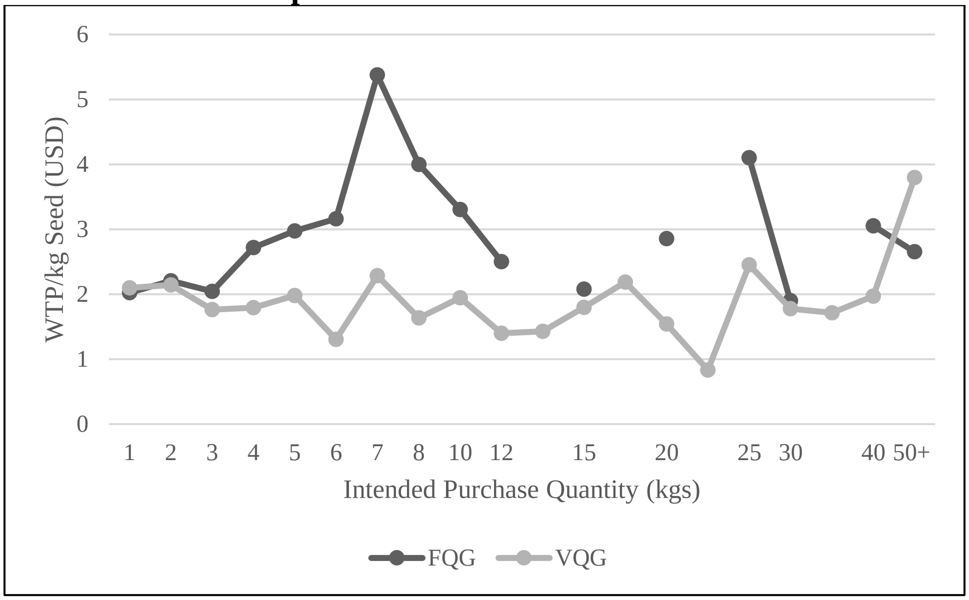
varieties, more consumers rated the taste of NUA45 beans as excellent.

A.4 Household Asset Index

Since collecting detailed data on household income or expenditures is often difficult, especially in developing countries, researchers often develop indexes to proxy for income and socioeconomic status (Filmer and Scott 2008). As such, a household asset index was developed to be used as a proxy for household economic status. Specifically, data from the survey on household, farm, and livestock assets are utilized. Commonly used ways to assess this is via the polychoric principal components analysis, which is an appropriate procedure for analyzing ordinal variables (Kolenikov and Angeles 2009). However, as we do not have many ordinal/categorical variables, we instead opt to put together a count index of all household, farm, and livestock assets. As the weight or financial importance of each item is different, we adjust the count of each item by their economic contribution (e.g., weight) following what is outlined by the Gates Foundation’s Agricultural Development Outcome Indicators (2010) and Njuku et al. (2011). The resulting scores for each household are then divided into four quartiles with quartile one indicating the lowest asset score and quartile four respondents having the highest asset score.

A.5 Estimation Results

Figure A.3: Average WTP/kg for Bean Seed (All Types) by Intended Purchase Quantity and Treatment Group



A.6 Estimation Results

A.6.1. Full Estimation Results for WTP (USD) for 2kgs of Bean Seed by Treatment Group

Table A.6.1A: Full Estimation Results for WTP (USD) for 2kgs of Bean Seed by Treatment Group

	Model 1			**Model 2**			**Model 3**			**Model 4**		
Variables	Coef.	Robust SE		Coef.	Robust SE		Coef.	Robust SE		Coef.	Robust SE	
Constant	3.87	0.19	***	3.07	1.58	*	4.12	0.22	***	3.16	1.59	**
Treatment (Base=VQG)												
Fixed Quantity Group (0/1)	1.64	0.28	***	1.55	0.32	***	0.07	0.38		-0.03	0.41	
Intended Purchase Qty, (Base: =2kg)												
IPQ < 2kg	--			--			-0.70	0.62		-0.69	0.93	
IPQ > 2kg	--			--			-0.30	0.19		-0.18	0.19	
Interaction terms												
FQG x IPQ < 2lg	--			--			0.14	0.91		0.20	0.93	
FQG x IPQ > 2kg	--			--			2.18	0.43	***	2.12	0.43	***
Controls												
Respondent is Household Head (0/1)	--			0.18	0.49		--			0.25	0.49	
Respondent is Female (0/1)	--			0.49	0.48		--			0.49	0.48	
Respondent's Age	--			0.01	0.01		--			0.01	0.01	
District (Base=Bindura)	--						--					
Centenary	--			0.49	0.79		--			0.43	0.82	
Chegutu	--			-0.10	0.96		--			-0.09	0.98	
Chikomba	--			2.45	2.39		--			2.56	2.39	
Chimanimani	--			-1.54	0.73	**	--			-1.85	0.75	**
Chipinge	--			-0.26	0.94		--			-0.25	0.95	
Chiredzi	--			-2.31	0.84	***	--			-2.30	0.86	***
Gokwe South	--			-0.38	0.88		--			0.41	0.86	
Goromonzi	--			1.27	0.96		--			1.17	0.98	
Guruve	--			0.06	0.77		--			-0.07	0.79	
Gutu	--			1.52	1.22		--			1.59	1.22	
Gweru	--			-1.18	0.71	*	--			-1.20	0.75	
Hurungwe	--			-1.62	0.75	**	--			-1.73	0.77	**
Hwedza	--			0.56	1.07		--			0.88	1.11	
Makonde	--			-1.18	0.78		--			-1.17	0.80	
Makoni	--			0.04	0.97		--			-0.05	0.99	
Masvingo	--			-1.16	0.92		--			-1.24	0.94	
Mazowe	--			-0.76	0.73		--			-0.60	0.73	
Mberengwa	--			1.22	0.83		--			1.12	0.86	

Table A.6.1A (cont'd)

Mount Darwin	--	0.60	1.09		--	0.19	1.11	
Mutare	--	-2.46	0.90	***	--	-2.25	0.91	**
Mutasa	--	0.03	0.72		--	-0.06	0.74	
Nyanga	--	0.02	0.76		--	-0.19	0.77	
Seke	--	-0.77	0.69		--	-0.83	0.71	
Zvimba	--	-0.56	0.76		--	-0.69	0.79	
Respondent Completed above Primary School Education (0/1)	--	0.40	0.29		--	0.29	0.29	
Household Size	--	0.13	0.14		--	0.12	0.14	
Bean among 2 most important crops grown for HH consumption (0/1)	--	-0.25	0.33		--	-0.01	0.34	
Bean among 2 most important crops grown for HH income (0/1)	--	-0.03	0.35		--	-0.19	0.35	
Total bean area last season (ha)	--	0.17	0.13		--	0.15	0.12	
Already purchased some bean seed for planting (0/1)	--	0.16	0.46		--	0.30	0.47	
Has received/expects to receive seed from the government (0/1)	--	0.23	0.39		--	0.17	0.40	
Previously aware of NUA45	--	0.00	0.28		--	-0.11	0.28	
Respondent's main employment: own farming (0/1)	--	0.05	0.44		--	0.01	0.44	
Experiment Outcome (Base=opportunity to purchase, did)								
Opportunity to purchase but refused	--	0.27	0.47		--	0.30	0.47	
No opportunity to purchase	--	-0.97	0.38	***	--	-0.99	0.38	***
Asset Quartile (Base=1, Lowest)								
Asset Quartile 2	--	-0.32	0.32		--	-0.08	0.32	
Asset Quartile 3	--	-0.37	0.37		--	-0.21	0.37	
Asset Quartile 4	--	-0.35	0.35		--	-0.30	0.35	
Post-estimation equality tests p-values:								
FQG=VQG: Equals 2kgs	--	--			0.8590	0.9520		
FQG=VQG: IPQ < 2kgs	--	--			0.8764	0.8248		
FQG=VQG: IPQ > 2kgs	--	--			0.0000	0.0000		
Number of Observations	1553	1553			1553	1553		
Number of Clusters (Households)	526	526			526	526		
R-Squared	0.0511	0.1573			0.0712	0.1750		

Note: * = p <0.10, ** = p <0.05, *** = p <0.01

Table A.6.1B: Full Estimation Results for WTP/2kg of Each Bean Seed Type by Treatment Group and Intended Purchase Quantity

	M1: Non-biofortified Bean			M2: Non-biofortified Bean			M1: Biofortified Bean without nutrition label			M2: Biofortified Bean without nutrition label			M1: Biofortified Bean with nutrition label			M2: Biofortified Bean with nutrition label		
Variables	Coeff	SE		Coeff	SE		Coeff	SE		Coeff	SE		Coeff	SE		Coeff	SE	
Constant	3.16	1.25	**	3.29	1.31	**	2.63	1.62		2.63	1.63		3.57	2.22		3.93	2.19	
Treatment Group (Base=VQG)																		
Fixed Qty Grp (0/1)	0.69	0.26	***	-0.34	0.40		1.70	0.37	***	0.48	0.54		2.28	0.45	***	0.50	0.77	
Intended Purch. Qty (IPQ) (Base: =2kg)																		
IPQ <2kgs	--			-0.35	1.17		--			--			--			--		
IPQ > 2kgs	--			-0.16	0.36		--			-0.15	0.42		--			-0.58	0.60	
Interaction terms																		
FQG x IPQ < 2kgs	--			0.69	1.25		--			--			--			0.62	1.48	
FQG x IPQ > 2kgs	--			1.37	0.49	***	--			1.63	0.63	***	--			2.21	0.86	***
Controls																		
HH Head (0/1)	0.18	0.43		0.2	0.42		0.08	0.51		0.16	0.51		0.25	0.69		0.35	0.69	
Female (0/1)	0.55	0.42		0.52	0.42		0.41	0.48		0.43	0.48		0.56	0.65		0.58	0.66	
Age	0.00	0.01		0	0.01		0.01	0.01		0.01	0.01		0.01	0.02		0.01	0.02	
District (Base=Bindura)																		
Centenary	0.57	0.76		0.51	0.78		0.75	0.84		0.77	0.88		0.10	1.09		0.19	1.14	
Chegutu	-0.04	0.85		-0.02	0.87		0.41	1.01		0.46	1.04		-0.78	1.33		-0.62	1.38	
Chikomba	1.94	2.04		1.98	2.04	**	2.26	2.17		2.37	2.18		3.09	3.30		3.32	3.34	
Chimanimani	-1.13	0.60	*	-1.30	0.62		-1.33	0.84		-1.56	0.87	*	-2.14	1.03	**	-2.19	1.08	**
Chipinge	0.11	0.93		0.08	0.95		-0.12	1.04		-0.05	1.06		-1.00	1.29		-0.86	1.30	
Chiredzi	-2.04	0.69	***	-2.05	0.70	***	-1.91	0.93	**	-1.84	0.97	*	-3.05	1.20	**	-2.94	1.24	**
Gokwesouth	-0.16	0.78		0.32	0.79		-0.10	0.99		0.66	0.97		-0.88	1.21		-0.25	1.20	
Goromonzi	0.61	0.80		0.47	0.81		1.66	1.02		1.63	1.03		1.43	1.34		1.41	1.36	
Guruve	-0.17	0.61		-0.30	0.61		0.47	0.87		0.46	0.88		-0.22	1.13		-0.22	1.16	
Gutu	1.04	0.94		1.01	0.95		1.50	1.38		1.65	1.38		1.86	1.76		2.07	1.78	
Gweru	-1.32	0.56	**	-1.37	0.63	**	-0.59	0.75		-0.62	0.76		-1.68	1.06		-1.96	1.06	*
Hurungwe	-1.59	0.64	**	-1.68	0.65	**	-1.23	0.77		-1.28	0.80		-2.15	1.10	*	-2.11	1.14	*

Table A.6.1B (cont'd)

Hwedza	0.25	0.87		0.46	0.89		0.70	1.22		0.96	1.26		0.47	1.44		0.77	1.51	
Makonde	-0.89	0.63		-0.88	0.63		-0.55	0.92		-0.55	0.95		-2.18	1.09	**	-2.03	1.14	*
Makoni	-0.21	0.78		-0.31	0.82		0.58	1.11		0.56	1.11		-0.27	1.30		-0.37	1.29	
Masvingo	-1.02	0.75		-1.11	0.77		-0.78	1.02		-0.76	1.04		-1.76	1.28		-1.71	1.30	
Mazowe	-0.77	0.59		-0.70	0.58		-0.92	0.84		-0.76	0.83		-0.67	1.11		-0.49	1.12	
Mberengwa	1.41	1.00		1.30	1.02		1.10	0.86		1.03	0.88		1.06	1.20		0.92	1.21	
Mhondorongezi	-0.28	1.12		-0.34	1.29		-1.54	1.13		-1.55	1.16		-1.47	1.28		-1.45	1.34	
Mountdarwin	0.35	0.92		0.19	0.92		0.81	1.26		0.44	1.29		0.53	1.50		0.26	1.54	
Mutare	-2.76	0.67	***	-2.65	0.70	***	-2.05	1.01	**	-1.84	1.01	*	-2.71	1.38	**	-2.54	1.36	*
Mutasa	-0.21	0.58		-0.23	0.59		-0.03	0.80		-0.09	0.83		0.26	1.05		0.33	1.10	
Nyanga	-1.16	0.62	*	-1.17	0.63	*	0.47	0.89		0.21	0.91		0.74	1.10		0.61	1.14	
Seke	-1.02	0.62		-1.10	0.63	*	-0.74	0.84		-0.73	0.87		-0.64	1.02		-0.52	1.07	
Zvimba	-0.85	0.63		-0.95	0.65		0.06	0.85		0.01	0.87		-1.02	1.07		-1.04	1.11	
Above Primary School Education (0/1)	0.27	0.25		0.18	0.25		0.27	0.33		0.22	0.33		0.67	0.39	*	0.57	0.39	
Household Size	0.13	0.12		0.13	0.12		0.13	0.12		0.11	0.12		0.14	0.19		0.14	0.19	
Bean: important for HH consumption (0/1)	-0.29	0.31		-0.09	0.32		-0.26	0.36		-0.12	0.37		-0.21	0.43		-0.04	0.44	
Bean: important HH income (0/1)	-0.17	0.32		-0.28	0.33		0.10	0.37		-0.03	0.37		-0.09	0.46		-0.20	0.46	
Bean area last sea. (ha)	0.19	0.08	**	0.17	0.08	**	0.14	0.15		0.13	0.15		0.20	0.20		0.18	0.20	
Already purchased some bean seed for planting (0/1)	-0.18	0.37		-0.12	0.38		0.42	0.55		0.54	0.55		0.24	0.66		0.36	0.68	
Has/expects seed from the gov't (0/1)	0.30	0.34		0.28	0.34		-0.11	0.42		-0.15	0.44		0.51	0.56		0.45	0.58	
Prev. aware of NUA45	0.13	0.25		0.07	0.25		-0.10	0.32		-0.19	0.32		-0.02	0.38		-0.11	0.38	
Main employment: own farming (0/1)	0.16	0.40		0.12	0.39		-0.03	0.52		-0.04	0.51		0.00	0.58		-0.02	0.58	

Table A.6.1B (cont'd)

Experiment Outcome (Base= opportunity to purchase & did)																		
Opportunity to purchase, refused	0.19	0.41		0.25	0.40		0.24	0.53		0.26	0.53		0.41	0.65		0.43	0.65	
No opportunity to purchase	-0.81	0.32	**	-0.85	0.32	***	-0.76	0.40	*	-0.75	0.40	*	-1.34	0.53	**	-1.36	0.53	**
Asset Quartile (Base=1, Lowest)																		
Asset Quartile 2	-0.45	0.27		-0.35	0.28		-0.02	0.37		0.21	0.38		-0.51	0.44		-0.28	0.44	
Asset Quartile 3	-0.17	0.32		-0.07	0.32		-0.37	0.41		-0.24	0.41		-0.47	0.50		-0.34	0.49	
Asset Quartile 4	-0.46	0.31		-0.41	0.31		-0.09	0.41		-0.05	0.41		-0.50	0.47		-0.42	0.48	
Number of Observations	509			509			520			520			524			524		
R-Squared	0.1708			0.1893			0.1723			0.1885			0.2103			0.2217		

Note: * = p <0.10, ** = p <0.05, *** = p <0.01

A.6.2. Heterogeneous Results – Bean Type

Table A.6.2A: Regression Estimation for WTP for 2kgs of bean seed by seed type and treatment group

	Model 1			Model 2		
Variables	Coef.	Std. Error		Coef.	Std. Error	
Constant	3.50	0.17	***	2.32	1.34	*
Treatment (Base=VQG)						
Fixed Quantity Group (0/1)	0.58	0.24	**	0.68	0.22	***
Bean Variety (Base=Non-biofortified)						
Biofortified without nutrition label	0.32	0.09	***	0.32	0.09	***
Biofortified with nutrition label	0.80	0.14	***	0.80	0.14	***
Interaction terms						
FQG x Biofortified seed without nutrition label	1.19	0.18	***	1.19	0.18	***
FQG x Biofortified seed with nutrition label	1.96	0.24	***	1.96	0.24	***
Other Respondent Controls Included		No			Yes	
Marginal Effect (treatment group = FQG)	1.63	0.28	***	1.74	0.25	***
Marginal Effect (bean type =Biofortified seed, no label)	0.91	0.09	***	0.91	0.09	***
Marginal Effect (bean type = Biofortified seed, with label)	1.77	0.12	***	1.77	0.12	***
Number of Observations		1553			1553	
Number of Clusters (Households)		526			526	
R-Squared		0.1013			0.1675	

Notes: Post-estimation equality of means tests for both Model 1 and 2, find that FQG x Biofortified seed without the nutrition label and FQG x Biofortified seed with the nutrition label are significantly different (p<0.01). Post-estimation equality of means tests for both Model 1 and 2, find that Biofortified bean seed without the nutrition label is significantly different (p<0.01) from Biofortified bean seed with the nutrition label.

Table A.6.2B: Estimation Results for WTP by Bean Seed Type, Treatment Group, and Intended Purchase Quantity (IPQ)

	Model 1			Model 2		
Variables	Coef.	Std. Error		Coef.	Std. Error	
Constant	3.77	0.23	***	1.74	1.36	
Treatment (Base=VQG)						
Fixed Quantity Group (0/1)	-0.24	0.36		-0.10	0.34	
Intended Purchase Qty (Base: IPQ=2kg)						
Intended Purchase Qty < 2kgs	0.07	0.55		0.04	0.56	
Intended Purchase Qty > 2kgs	-0.37	0.21	*	-0.34	0.21	
Bean Seed Type (Base: Non-Biofortified Bean)						
Biofortified, no nutrition label	0.44	0.27	*	0.45	0.27	*
Biofortified, with nutrition label	1.21	0.33	***	1.21	0.33	***
Treatment Group x Intended Purchase Quantity						
FQG x IPQ < 2kgs	-0.19	0.87		-0.19	0.88	
FQG x IPQ > 2kgs	1.19	0.41	***	1.17	0.41	***
Treatment Group x Bean Seed Type						
FQG x Biofortified, No Label	0.80	0.34	**	0.78	0.34	**
FQG x Biofortified, with Label	1.08	0.44	**	1.08	0.44	**
Bean Seed Type x Intended Purchase Qty						
BF no label x IPQ < 2kgs	-1.40	0.39	***	-1.32	0.39	***
BF no label x IPQ > 2kgs	-0.11	0.29		-0.12	0.30	
BF with label x IPQ < 2kgs	--			--		
BF with label x IPQ > 2kgs	-0.45	0.37		-0.45	0.38	
Treatment Group x IPQ x Bean Seed Type						
FQG x IPQ > 2kgs x BF no label	0.41	0.43		0.44	0.43	
FQG x IPQ > 2kgs x BF with label	0.97	0.55	*	0.97	0.55	*
FQG x IPQ < 2kgs x BF no label	--			--		
FQG x IPQ < 2kgs x BF with label	-0.35	0.77		-0.35	0.75	
Other Respondent Controls Included	No			Yes		
Number of Observations	1553			1553		
Number of Clusters (Villages)	526			526		
R-Squared	0.1177			0.1674		

Notes: when Treatment is not specified, it corresponds to VQG; when bean type is not specified, it corresponds to the non-biofortified bean seed; when intended purchase quantity is not specified, it refers to IPQ = 2kgs; * = p <0.10, ** = p <0.05, *** = p <0.01.

A.6.3. Heterogeneous Effects – FQG Bias Overall and by Intended Purchase Quantity for Bean Land Size, Respondent Gender, and Respondent Wealth Status

Table A.6.3A: Estimation Results of FQG Bias by Respondent Heterogeneity

Land Area	**Bean Land Size**			**Respondent Gender**			**Respondent Wealth**		
Variables	Coef.	Std. Error		Coef.	Std. Error		Coef.	Std. Error	
Constant	1.80	1.36		1.42	1.38	***	1.87	1.23	
Treatment (Base=VQG)									
Fixed Quantity Group (0/1)	1.64	0.35	***	1.94	0.35	***	1.82	0.33	***
Bean Land Area (Base=Small)									
Large Bean Land Area (0/1)	0.21	0.41		--			--		
Interaction terms									
FQG x Large Bean Land Area	0.28	0.56		--			--		
Respondent Gender (Base=Male)									
Female (0/1)	--			0.62	0.60		--		
Interaction terms									
FQG x Female	--			-0.11	0.63		--		
Respondent Wealth (Base=Low)									
High (0/1)	--			--			-0.03	0.33	
Interaction terms									
FQG x High Wealth Status	--			--			-0.21	0.51	
Other Respondent Controls Included	Yes			Yes			Yes		
Marginal Effect (treatment group = FQG)	1.77	0.25	***	1.89	0.28	***	1.72	0.25	***
Number of Observations	1553			1553			1553		
Number of Clusters (Households)	526			526			526		
R-Squared	0.1550			0.1645			0.1529		

Note: * = p <0.10, ** = p <0.05, *** = p <0.01

Table A.6.3B: POLS IPQ Estimation Results by Respondent Heterogeneity

Variables	Coef.	Std. Error	p-value	Coef.	Std. Error	p-value
Bean Land Area	**Small Bean Land Area**			**Large Bean Land Area**		
Constant	2.34	1.48		1.74	2.13	
Fixed Quantity Group (0/1)	-0.05	0.41		0.27	0.68	
Intended Purchase Qty Less than 2kg	-0.14	1.04		0.46	0.46	
Intended Purchase Qty More than 2kg	-0.83	0.24	***	-0.63	0.28	**
FQG x Intended Purchase Qty Less than 2kg	-0.67	1.21		0.15	0.95	
FQG x Intended Purchase Qty More than 2kg	2.13	0.44	***	2.42	0.81	***
Other Respondent Controls Included		*Yes*			*Yes*	
Post-estimation p-value for Small=Large: FQG x IPQ > 2kgs	*0.815*					
Number of Observations		844			709	
Number of Clusters (Villages)		287			239	
R-Squared		0.1918			0.2054	
Respondent Wealth Status	**Low Wealth Status**			**High Wealth Status**		
Constant	2.24	1.03	**	1.83	2.35	
Fixed Quantity Group (0/1)	0.58	0.40		-0.56	0.63	
Intended Purchase Qty Less than 2kg	0.31	0.68		--		
Intended Purchase Qty More than 2kg	-0.56	0.27	**	-0.95	0.23	***
FQG x Intended Purchase Qty Less than 2kg	-1.02	0.82			0.67	***
FQG x Intended Purchase Qty More than 2kg	1.68	0.47	***	2.90	0.72	***
Other Respondent Controls Included		*Yes*			*Yes*	
Post-estimation p-value for Low=High: FQG x IPQ > 2kgs	*0.240*					
Number of Observations		783			770	
Number of Clusters (Villages)		266			260	
R-Squared		0.2038			0.1495	
Respondent Gender	**Male Respondents**			**Female Respondents**		
Constant	4.14	1.59	***	1.74	2.13	
Fixed Quantity Group (0/1)	-0.21	0.48		0.40	0.55	
Intended Purchase Qty Less than 2kg	-1.22	0.23	***	0.97	0.47	**
Intended Purchase Qty More than 2kg	-0.91	0.28	***	-0.63	0.27	**
FQG x Intended Purchase Qty Less than 2kg	1.30	0.82		-1.68	0.82	**
FQG x Intended Purchase Qty More than 2kg	2.57	0.54	***	1.70	0.59	***
Other Respondent Controls Included		*Yes*			*Yes*	
Post-estimation p-value for Male=Female: FQG x IPQ > 2kgs	*0.217*					
Number of Observations		850			703	
Number of Clusters (Villages)		288			238	
R-Squared		0.2245			0.2007	

*Note: * = p <0.10, ** = p <0.05, *** = p <0.01; Given the small sample size of IPQ<2kgs, we do not test significant differences across land size, wealth status, or respondent gender. Each column within a heterogeneity variable represents a separate regression.