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Integrating Economic Analysis with a Randomized Controlled Trial: Willingness-to-Pay for a New Maternal Nutrient Supplement

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Abstract

Maternal nutrition during pregnancy can have significant implications for a child's prenatal growth and development, and undernutrition experienced during the prenatal period increases the risk of early childhood morbidity and mortality and can permanently impair a child's physical growth and cognitive development. We use new data from Ghana generated using contingent valuation and experimental auction techniques to estimate willingness-to-pay (WTP) for LNS, a new nutrient supplement aimed at preventing maternal undernutrition during pregnancy. We also explore the relative importance of individual and household characteristics as well as information about the long-term benefits of preventing undernutrition on WTP. We find that WTP is positive for a large majority of individuals in our samples, and the level of WTP varies significantly with individual and household characteristics including gender, household food insecurity, and household expenditures. These findings suggest important policy implications for the development of delivery options and pricing mechanisms for LNS.

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Maternal and early childhood undernutrition are responsible for millions of childhood deaths and incidences of disease every year in developing countries (Black et al. 2008). Beyond the short term effects, children who survive undernutrition in the early stages of life can suffer permanent developmental impairments that stifle their cognitive functioning and physical growth and ultimately constrain their economic productivity in adulthood (Martorell 1999; Victora et al. 2008). Given the short and long term costs associated with maternal and early childhood undernutrition, its prevalence across the developing world is staggering. Approximately 11 percent of all children born at term in developing countries are low birth weight[1], one third of all children under age five are stunted[2], and in most countries, 10-19 percent of women age 15-49 have a low body mass index[3] (Black et al. 2008). Children are particularly vulnerable to undernutrition during their first two years of life, including the prenatal period, with potential impacts including growth faltering (i.e. deficits in growth relative to reference values), delayed motor, cognitive, and behavioral development, and increased morbidity and mortality (Martorell 1999, Victora et al. 2008). Moreover, the effects can permanently limit a child's developmental, educational, and productive potential since it may be impossible for improved nutrition later in life to fully compensate for the deficits undernutrition imposes on the body during this vulnerable period. The long-term result can be lower attained schooling, shorter adult stature, lower income, and decreased offspring birth weight (Behrman, Alderman, and Hoddinott 2004; Alderman and Behrman 2006; Alderman, Behrman, and Hoddinott 2007; Victor et al. 2008).

In recognition of children's vulnerability during early development, the International Lipid-Based Nutrient Supplement (iLiNS) Project is administering a targeted randomized controlled nutrition trial in Ghana to evaluate the efficacy of new products collectively called lipid-based nutrient supplements (LNS) that are formulated for the *prevention* of maternal and early childhood undernutrition. If successful, LNS will likely become a candidate intervention for preventing maternal and early childhood undernutrition on a large scale. Yet a successful transition from efficacy in a controlled trial to effectiveness in real-world settings is not automatic (Glasgow, Lichtenstien, and Marcus 2003) and fundamentally depends on consistent delivery to and consumption by households outside the context of the controlled trial.

Even if LNS significantly improves maternal nutritional status and child health and developmental outcomes, whether or not it is a worthwhile investment from the perspective of a resource-constrained household is uncertain for a number of reasons. First, LNS is formulated to be preventative, not therapeutic. Will households choose to invest limited resources in a nutritional product before a mother or young child exhibits signs of undernutrition? Related, will households value LNS when many of the short-run effects, such as improved micronutrient stores and improved birth weight and length, may not be easily observable to or directly valued by households? Moreover, will households choose to invest in LNS in the short-term when many of the benefits are only realized in the long-run in the form of economic returns to improved cognitive and physical capacity in adulthood?

This article uses estimates of willingness-to-pay (WTP) for LNS generated alongside the randomized controlled nutrition trial to begin answering these questions. We employ both contingent valuation and experimental auctions methods to measure individuals' WTP for LNS formulated for maternal consumption during pregnancy. Beyond raw estimates of willingness-to-pay, designing strategies to effectively target, promote, and deliver LNS to households may depend on the factors that are systematically associated with WTP. To this end, we estimate the individual and household characteristics that influence WTP for LNS, and we also assess the impact of exposure to information about the long-term benefits of preventing undernutrition on WTP. This analysis is relevant for the policy development and private and social marketing of LNS. It also provides insight into how valuation of a nutrient supplement is shaped in the short run when many of the benefits are observable only in the long run and thus has broad application to other products and services with similar streams of costs and benefits.

Our preliminary[4] findings suggest that almost all contingent valuation survey respondents and experimental auction participants have a positive WTP for LNS during pregnancy. The average hypothetical WTP for a day's supply of LNS is $0.56, while the average WTP from the auctions is $0.26. We find that the level of hypothetical WTP varies significantly with gender, employment status, the number of children under age five in the household, food expenditures, and household food insecurity, while previous use of a nutrient supplement during pregnancy, income, and the cost of transport to the hospital are associated with WTP generated from the auctions. We also find that 36% of auction participants have redeemed a coupon to purchase more LNS after the auction, and the probability of redeeming a coupon increases for people who are exposed to information about the long-term benefits of preventing undernutrition.

Background

Undernutrition is defined as a condition in which one or more of the body's nutrients are below normal levels, which can manifest as intrauterine growth restriction (IUGR)[5], stunting (low height-for-age), wasting (low weight-for-age), low body mass index, and micronutrient deficiencies (Allen and Gillespie 2001). During *in utero* development, the growth of the fetus is very dependent on the mother's nutritional status, which encompasses both nutritional status at conception as well as health and nutrition during pregnancy (Allen and Gillespie 2001; de Onis 2001). Poor maternal nutrition can result in low birthweight, preterm birth, or intrauterine growth restriction in which the development of the fetus is constrained in utero, leading to a much higher likelihood of infant morbidity and mortality and impaired cognitive development (Allen and Gillespie 2001).

Lipid-based food products that have been fortified with multiple micronutrients have had success in the treatment of severely undernourished children (Chaparro and Dewey 2010; Ashenworth 2006). The next step is to evaluate the efficacy of similar products at a much lower daily ration but with a high concentration of micronutrients to *prevent* maternal and early childhood undernutrition. Supplementing the everyday diet of women during pregnancy with LNS is a novel approach to tackling maternal undernutrition and improving the growth and development of children. LNS contain vegetable fat, peanut paste, milk powder, sugar, and a vitamin-mineral mix, and 20 gram daily doses taken throughout pregnancy meet the micronutrient needs of pregnant women. And, because the micronutrients in LNS are embedded in a lipid-based paste, the supplements also provide some macronutrients (fats, protein, and carbohydrates).

The next section of this article develops a simple household model that focuses on the production of maternal and child health and demonstrates how nutrient supplements like LNS fit into a household's economic decision-making framework.

Conceptual Model

The formation of human capital (i.e., skills and abilities) and its role over the life course in determining socioeconomic outcomes has been the topic of a considerable body of literature that has evolved over the years (Cunha et al. 2006 provide a review). More recently, the hypothesis that health capital (i.e., stock of acquired health) accumulated in early childhood has a causal effect on subsequent human capital formation, schooling outcomes, and adult labor market outcomes has gained attention (e.g., Alderman et al. 2001; Hoddinott et al. 2008; Yamuchi 2008; Maluccio et al. 2009). The following basic household model provides a framework for describing households' economic behavior in the context of maternal and child health and highlights their role in determining a child's human capital accumulation.

Following Glewwe and Miguel (2008), the starting point is a two period unitary household model featuring household production of the health and human capital of a single child. Period one begins at conception and extends through the first two years of life, forming the basis of the child's health over his/her life course. The health and nutritional status of the mother during pregnancy, which is directly influenced by prenatal investments, is one determinant of the child's health throughout this period. In the second period, the child accumulates human capital, which, like the child's health, is directly valued by the household. The unitary household utility function can be defined as

$$U = u(X_1, X_2, H_1^c, H_2^c, S_2^c) \tag{1}$$

where X_t $(t = 1,2)$ are vectors of consumption goods in each period, H_t^c are child health in each period, and S_2^c is the child's human capital in period two[6]. The household maximizes its utility subject to production functions for child (denoted by the superscript c) and maternal (denoted by the superscript m) health, defined as

$$H_1^c = h(H_1^m, X_1^c, I_1^c, Z_1^c, HE_1, \varphi^c) \tag{2}$$

$$H_1^m = h(H_0^m, X_1^m, I_1^m, Z_1^m, HE_1, \varphi^m) \tag{3}$$

$$H_2^c = h(H_1^c, X_2^c, I_2^c, Z_2^c, HE_2, \varphi^c). \tag{4}$$

The vectors X_t^j (for $j = m, c$) are consumption goods that influence maternal and child health production, I_t^j are health inputs or investments that do not directly augment utility (e.g., prenatal care, immunizations, and nutritional supplements such as LNS), Z_t^c are exogenous individual and household characteristics that influence maternal and child health (such as birth spacing, child gender, and parents' education and nutritional knowledge), HE_t is the exogenous health environment (access to health care, air and water quality, etc.), and φ^c and φ^m are innate child and mother healthiness, respectively. H_0^m is the mother's pre-pregnancy health status.

Household utility is also maximized subject to a production function for the child's human capital, defined as

$$S_2^c = h(H_1^c, H_2^c, E_2, \tau^c), \tag{5}$$

where E_2 are inputs into human capital accumulation (e.g., schooling, parent time), and τ^c is the child's innate ability. The child's human capital also directly depends on his/her health in both periods, creating an incentive for the household to invest in the child's health not only because of its utility value but also because of its role in human capital formation. Allowing for borrowing and saving between the two periods, denoted B, at the market interest rate, r, the household also faces budget constraints in periods one and two, respectively defined as

$$P_1^x X_1 + P_1^i I_1 = Y_1 + B \tag{6}$$

$$P_2^x X_2 + P_2^i I_2 + P_2^e E_2 = Y_2 + B(1 + r) \tag{7}$$

where P_t^x and P_t^i are prices for consumption goods and health inputs in each period, P_2^e is the price of human capital inputs in period two, and Y_t is exogenous household income in each period.

This simple household model shows not only the inter-period connectedness of maternal and early childhood health and human capital formation but also demonstrates that households have an array of choices, given their constraints, in terms of how and when to invest in the health of their children. As previously noted, even if shown to be highly efficacious in improving health and developmental outcomes in the setting of a controlled trial, the ultimate effectiveness of a product like LNS hinges on its acceptance and regular consumption under real-world conditions. Outside of a clinical trial setting, households will face both monetary and non-monetary costs associated with consuming LNS on a daily basis. Given household preferences and constraints, the costs associated with LNS consumption coupled with the stream of expected benefits may influence whether a household values the product enough to invest in it. And because household resource allocation decisions may not always coincide with the expectations of nutritionists or policy makers, evaluating whether households are willing to invest in LNS and at what price as well as the factor that systematically influence households' valuation of LNS are critical components of assessing the potential for LNS to tackle undernutrition.

WTP for Health and Nutritional Products in Developing Countries

This study uses both contingent valuation and experimental auction methods to elicit WTP for LNS during pregnancy. Contingent valuation is not a new approach to valuing non-market goods and new products in developing countries, including health and nutritional products, and a number of elicitation methods have been employed. Onwujekwe (2001) and Bhatia and Fox–Rushby (2002) elicited hypothetical WTP for insecticide treated bednets in rural Nigeria and India, respectively, using bidding formats in which respondents were led through a pre-specified bidding tree and answered dichotomous choice questions about their willingness-to-pay at specific prices before stating their maximum WTP. Based on OLS estimates, Onwujekwe (2001) found that respondent gender, years of education, household size, and the presence of malaria in the household were among the significant determinants of WTP. In another study, Cropper et al. (2004) estimated Ethiopian households' WTP to avoid malaria by eliciting WTP for a hypothetical malaria vaccine. The study asked participants if they would be willing to pay a randomly drawn price and how many vaccines they would purchase at that price. Truncated poisson model estimates revealed that the demand for the vaccine increased significantly with income, literacy, and being married while demand decreased with price, age, number of children in the household, and being female. Finally, Gustafsson-Wright, Asfaw, and van der Gaag (2009) used a double-bound dichotomous choice method to elicit WTP for a new health insurance product in Namibia and found that respondents were, on average, willing to pay 2.25% of their monthly income on health insurance. Using a selection model, WTP was shown to be lower for women than men, negatively associated with age, and positively associated with education and per capita household consumption.

While less common than contingent valuation studies, experimental approaches are also being increasingly utilized in developing country settings to estimate WTP for health and nutritional products (e.g., Masters and Sanogo 2002; Hoffmann, Barrett, and Just 2008; De Groote, Kimenju, and Morawetz 2010a; De Groote et al. 2010b; Dupas 2010). De Groote, Kimenju, and Morawetz (2010a) used a modified individual Becker-DeGroote-Marschak (BDM) auction mechanism in Kenya to estimate consumer WTP for biofortified maize. Although the study found that Kenyan consumers were, on average, willing to pay a 24% premium for fortified maize, there was no significant impact of either socioeconomic characteristics or consumers' knowledge of nutritional quality on WTP. In a related study, De Groote et al. (2010b) used BDM auctions to evaluate the effect of information on consumers' WTP for biofortified maize in Ghana. Half of the respondents received information on the nutritional benefits of orange biofortified maize before bidding on white maize, yellow maize, and orange fortified maize. The study found that nutritional information had a significant positive effect on WTP for orange fortified maize and concluded that the dissemination of information can help overcome consumer preferences toward more familiar products. Finally, Dupas (2010) designed an experiment using vouchers to test the effect of learning about nonmonetary usage costs on WTP for long-lasting insecticide treated bednets in Kenya. The study found that households who initially received free or highly subsidized bednets had higher stated and observed WTP for another net a year later, suggesting that subsidies increased experimentation with the new nets and that households initially overestimated the nonmonetary costs associated with using the nets. Further, households with more 'neighbors' who received a free or highly subsidized net were found to be more likely to purchase a net themselves.

This article contributes to the literature on WTP for health and nutritional products in developing countries by focusing on a new nutrient supplement that, unlike bednets or vaccines that have fairly immediate and transparent benefits, is characterized by short-run costs while many of the benefits accrue only in the long-run. This study is also unique in that it integrates a contingent valuation study with a randomized controlled trial, allowing for estimates of the role of learning about the new product through exposure to others using the product in determining WTP. Finally, we take experimental auction estimates of WTP a step further by looking at purchasing behavior after an auction, which is a particularly informative addition for products like LNS that must be habitually procured and consumed to produce the intended effects.

We now turn to our willingness-to-pay studies, beginning with a description of the sample, the methods employed, and the results from the contingent valuation study and then presenting the sample, methods, and results from the experimental auctions. We conclude with a discussion of the policy implications that stem from the results of both studies.

Hypothetical Willingness-to-Pay

We use contingent valuation methods to elicit hypothetical WTP for LNS from a subsample of the iLiNS study population. The nutritional objectives of the iLiNS study are to evaluate the efficacy of LNS on the nutritional status of pregnant women and the health and development of their children. The contingent valuation study compliments these objectives by addressing some forward-looking questions about the value of LNS to its potential users outside the context of the trial and the factors that are systematically associated with that value.

Description of iLiNS Study and Contingent Valuation Sample

Recruitment and enrollment of pregnant women into the iLiNS study began in December of 2009 and is ongoing. All women attending prenatal clinics at three hospitals in the Manya Krobo and Yilo Krobo districts in the Eastern Region of Ghana are recruited to participate in the trial, so enrollment is rolling depending on the timing of prenatal visits. Eligible and willing participants are randomized into one of the trial's three arms. The control arm receives daily iron-folic acid tablets, another arm receives daily multiple micronutrient tablets, and the third arm receives LNS daily.

Our hypothetical WTP dataset currently includes 302 respondents randomly selected from the iLiNS study[7]. Within a household, the respondent for the hypothetical WTP study is randomly assigned as either the woman participating in the iLiNS study or the head of household in which she lives. Table 1 provides definitions and summary statistics of the individual and household characteristics of the respondents in the hypothetical WTP sample. The sample is approximately 66% female. Respondents are 32 years old on average, have 8.38 years of schooling, and a majority (88%) reports being employed in the past 12 months. Average per capita daily expenditures on food are $1.25.

Methods

The baseline contingent valuation survey is administered at approximately 20 weeks of gestation of the woman participating in the iLiNS study. Willingness-to-pay for a day's supply (one 20 gram sachet) of LNS during pregnancy is elicited using a bidding tree structure, whereby after a respondent is read a brief statement about LNS (locally know as nkate pa), s/he is asked if s/he would be willing to pay anything to purchase a single sachet of LNS if it were available at a nearby kiosk. Because some respondents are receiving LNS for free as part of the randomized trial, all respondents are asked to pretend that the iLiNS study has run out of money so the trials are ending that day. If the respondent indicates s/he is willing to pay at least something for LNS, s/he is then led through a bidding tree of prices for LNS, with the price increasing or decreasing depending on the response to a dichotomous choice question[8] at each node in the tree. Once an end node in the tree is reached, the respondent is asked his/her maximum WTP. To control for starting point bias, the starting price is randomized across respondents as either GH¢ 0.20, GH¢ 0.50, or GH¢ 1.00 (approximately $0.13, $0.33, or $0.66). Regardless of the starting point price, the prices in each bidding tree are the same and range from GH¢ 0.10 to GH¢ 1.50 (or roughly $0.07 to $1.00). A sample bidding tree is presented in figure 1.

Given the rolling sample design of the trial, households enrolled in the study early on, particularly those not randomized into the LNS arm of the trial, do not have the opportunity to learn much about the potential costs and benefits of consuming LNS simply because LNS households are relatively rare. Over time as the number of LNS households increases, the potential to learn from others by observing their outcomes (e.g., maternal health and birth outcomes) and costs (e.g., the time necessary to consume LNS) likewise increases. Because an individual's WTP for LNS may depend on both their own experience with the product and what they have learned through observation and conversation with other people using the product, after indicating their maximum WTP respondents are asked how many women they know outside their own household who have or are currently taking LNS during pregnancy. Respondents are also asked about their role in food preparation and household purchase decisions as well as previous experiences with undernutrition during pregnancy and early childhood.

We are also collecting baseline data on household socioeconomic and demographic characteristics, expenditures, food security, and individual discount rate.

Baseline socioeconomic and demographic characteristics are collected using a household survey. Food expenditure data is based on one-week recall by the household member responsible for food preparation of the quantity and amount spent on a comprehensive list of food and drinks. Food security data is based on the Household Food Insecurity Access Scale developed by USAID's Food and Nutrition Technical Assistance (FANTA) project (Coates, Swindale, and Bilinsky 2007). Each household receives a score between 0-27 base on the answers to a set of nine frequency of occurrence questions (never, rarely, sometimes, often) about food insecurity. Finally, we also generate a measure of relative individual discount rate by playing a game in which a respondent is shown a tin of rice and is then asked to measure out the quantity of rice that would make him/her indifferent between receiving the single tin of rice in a week and the tin plus the addition amount measured in a month[9].

Empirical Model

The empirical analysis of the hypothetical WTP data aims to estimate WTP for LNS and the factors associated with it. Although WTP is potentially left-censored at zero, we observe just 12 zeros (3.92%) in our sample, so we use OLS to estimate the determinants of WTP, which does not depend on the assumptions of normality and homoskedasticity for consistency[10]. We model hypothetical WTP for LNS during pregnancy across $i = 1, 2, \ldots, N$ respondents as $WTP_i = X_i'\beta + u_i$, where WTP_i is willingness-to-pay for a day's supply of LNS, X_i is a vector of observed individual and household characteristics, and u_i is the error term.

Results

Table 2 summarizes hypothetical WTP for LNS. Mean maximum WTP for a day's supply of LNS across the sample is $0.56, ranging from zero to $2.00. Across the gender of the respondent, women, on average, report a lower WTP than men, and this difference across men and women is statistically significant at the 5% level. Interestingly, all respondents indicating they are not willing to pay anything for LNS are women (6% of all women report a zero WTP). The most common reasons given by respondents who are not willing to pay anything for LNS are not enough money and fear of the possible side effects.

The linear regression estimates of the influence of a set of individual and household characteristics on stated maximum WTP for a day's supply of LNS are reported in table 3. Among the individual characteristics in the model, gender and employment status are significantly associated with WTP. All else equal, maximum WTP for a day's supply of LNS during pregnancy is approximately $0.22 lower ($p < .01$) for women than men, and there are several possible explanations for this result. First, it may be reflecting a tighter budget constraint faced by women than men in a household. It could also be the result of gender differences in the perceived benefits of improving maternal nutrition during pregnancy. Or, the gender difference in WTP may be reflecting differences in the costs associated with consuming LNS, since most of the non-monetary costs (e.g., daily time costs associated with preparing and consuming foods supplemented with LNS) fall to women during pregnancy. In terms of employment status, respondents who have been continuously unemployed for at least the past 12 months report a \$0.14 lower ($p<.05$) WTP for a day's supply of LNS than do employed respondents.

A respondent's individual discount rate is not significant in the model. Given that many of the potential benefits to the child of improved maternal nutritional status during pregnancy are long-term in nature, we would expect an individual's discount rate to be associated with his/her WTP for LNS. If respondents are either not aware of the potential long-term benefits or are uncertain about the strength of the link been maternal nutrition and a child's long-term growth and development, however, this might explain the lack of a statistically significant relationship between discount rate and WTP. Finally, the number of women the respondent knows outside his/her household who are taking LNS is also insignificant in the model. This may be attributable to the fact that this is baseline hypothetical WTP data, and as respondents progress through the randomized trial over time, the role of exposure to other women taking LNS may become more important. It may also be related to the fact that we cannot yet control for treatment group within the randomized trial[11], and exposure to others taking LNS may be particularly important for those randomized into a non-LNS treatment group.

Turning now to household characteristics, there is a statistically significant ($p<.01$) relationship between a household's food insecurity access score and WTP for LNS. The negative coefficient on HFIA score indicates that, *ceteris paribus*, respondents in more food insecure households have a lower WTP for LNS than those in relatively more food secure households. However, the influence of a household's food security status varies across the gender of the respondent. The interaction between the respondent's gender and the HFIA score reveals that although being female and being from a food insecure household are both negatively related to WTP, females' WTP for a day's supply of LNS significantly increases ($p < .01$) with increasing household food insecurity. Since a majority of the female respondents in our sample are responsible for purchasing (63%) and preparing (91%) food for the household while only 9% of men in the sample are responsible for purchasing food and 7% are involved in preparing food, women may be more acutely aware of the household's food security status and therefore place a higher value on preventing nutrient deficits when the household is facing food insecurity.

The number of children under five and food expenditures are also significant household-level characteristics significantly associated with WTP. For each additional child under age five in the household, stated WTP is almost \$0.06 lower, while each additional dollar of daily per capita household expenditures on food is predicted to increase WTP by approximately \$0.01. Whether a respondent (or a woman in the respondent's household) has previously experienced an unhealthy pregnancy as a result of undernourishment does not have a significant influence on WTP for LNS during pregnancy.

One final interesting result is that when WTP elicitation occurs in June, maximum WTP is \$0.26 higher ($p < .01$) than when it occurs in all other months. June marks the end of the major rainy season in the Eastern Region in Ghana and is a time of harvest and plentiful food. Although most respondents in our sample are not employed in the agricultural sector, non-farming households generally face lower staple food prices in June (USDA 2009) and thus may be less resource constrained.

Experimental Auctions

While stated-preference methods such as contingent valuation for eliciting WTP are frequently employed by researchers interested in estimating the value of goods or services not available in markets, the validity of these estimates is often called into question due to the potential for hypothetical bias, as respondents do not have an incentive to provide carefully considered, honest answers (Lusk and Shogren 2007). Experimental auctions designed to elicit incentive-compatible estimates of WTP, which implies that respondents are motivated to report a WTP that truly reflects his/her value of the product (Lusk and Shogren 2007), are an increasingly popular alternative to hypothetical techniques. We are currently undertaking a series of experimental auctions to complement the estimates of WTP generated from the contingent valuation study.

Description of Experimental Auction Sample

The participants in the experimental auctions are pregnant women who are not participating in the iLiNS study[12]. Auction participants are recruited from an antenatal clinic at Akuse Government Hospital in the Manya Krobo District, which is located outside the iLiNS project study area. To date, 115 women have participated in an auction.

Table 4 provides definitions and summary statistics of the individual and household characteristics of auction participants. Approximately 13% of the participants are the head of their household. The average age of the women in the sample is almost

28 years, and they have 6.77 years of education on average. Most of the women (73.91%) report having previously used some type of nutrient supplement during pregnancy.

Methods

The auctions are held in a covered outdoor space at the antenatal clinic at Akuse Government Hospital. As participants arrive they are given an ID number and assigned an enumerator who records their bids and answers questions as the auction progresses. They are also given an envelope containing GH¢ 4 (approximately $2.67), which is intended to compensate participants for their time and also serve as their budget to bid on and purchase LNS, although participants are allowed to bid higher than GH¢ 4.

The auction format follows the Becker-Degroot-Marschak (BDM) structure, whereby participants submit a bid for the auction item and then a market price is randomly determined. If their bid is equal to or above the market price, the participant purchases the item at the market price (Becker, Degroot, and Marschak 1964; Lusk and Shogren 2007). After explaining the auction procedure[13], the auction facilitator runs a demonstration auction with enumerators and a series of practice auctions for candy with the participants to familiarize them with the auction procedure and potential outcomes. After the demonstration and candy auctions but before submitting their bids for LNS, participants are read an information statement about LNS and the benefits of preventing maternal and early childhood undernutrition. In a randomly selected half of the auctions, participants are read information about LNS usage, participate in a taste test, and are read information about the short-term benefits of preventing undernutrition. In addition to all of the information about usage and short-term benefits as well as the taste test, participants in the other half of the auctions receive additional informational about the long-term benefits of preventing undernutrition. This randomized information treatment is designed to capture the impact of drawing participants' attention to the potential long-term benefits of consuming LNS on their valuation of the product.

Before submitting their real bids for a week's supply of LNS, participants submit two practice bids for LNS that are not actually transacted. After each bid is submitted, a random market price[14] is determined by asking a participant to pull a slip of paper printed with a price out of a bag. The random market price is drawn from a normal distribution with a mean of GH¢ 2 (approximately $1.33) and standard deviation of GH¢ 0.90 (approximately $0.60). After the market price is determined, participants who bid at or above the market price purchase a week's supply of LNS at the market price. The auction sessions conclude with a short questionnaire to gather individual and household socioeconomic characteristics from participants. Before participants leave the auction, they are told that since LNS should be taken regularly for an extended period of time, they will have the opportunity to purchase more LNS (or if they did not bid high enough to purchase the product during the auction but later decide to purchase it) in the coming weeks. Participants are given two coupons that each entitle them to purchase an additional week's supply of LNS at the market price determined during the auction. Participants are informed that if they chose to redeem their coupons, they will have to rely on their own funds. After the auction, enumerators rank their assigned participants' comprehension of the auction procedure on a scale of 1-5 where 1 is a poor understanding and 5 is an excellent understanding.

Empirical Models

Like the hypothetical WTP data, there are very few (1.74%) zero bids, so we estimate the individual and household characteristics associated with WTP using OLS. WTP generated from the experimental auctions may have errors clustered at the auction level. To account for potential clustering, we model auction WTP as $WTP_{ia} = X_{ia}'\beta + u_{ia}$ across $a = 1, 2, \ldots, A$ auctions and $i = 1, 2, \ldots, N_a$ participants in each auction.

We are also interested in auction participants' purchasing behavior after the auctions. To estimate to probability of redeeming a coupon to purchase LNS after an auction, define a latent model across $a = 1, 2, \ldots, A$ auctions and $i = 1, 2, \ldots, N_a$ participants in each auction as $Purchase_{ia}^{*} = X_{ia}'\beta + u_{ia}$, where $Purchase_{ia}^{*}$ is an auction participant's propensity to use a coupon to purchase additional LNS. This propensity is unobserved, and instead we observe

$$Purchase_{ia} = \begin{cases} 1 \; if \; Purchase_{ia}^{*} > 0 \\ 0 \; if \; Purchase_{ia}^{*} \leq 0. \end{cases} \tag{8}$$

Based on this latent model, we use a logit[15] specification to estimate the probability of using a coupon to purchase LNS, defined as (Cameron and Trivedi 2005) $Prob[Purchase_{ia} = 1 | X_{ia}] = \Lambda(X_{ia}'\beta)$, where $\Lambda(\cdot)$ is the cumulative distribution function of the logistic distribution, and X_{ia} is a vector of regressors including the price of LNS as determined in the auction.

Results

Table 5 summarizes auction bids for a day's supply[16] of LNS. The average bid for a single sachet of LNS across all auctions and participants is $0.26, ranging from zero to $0.67. Average bids are about $0.03 higher when auction participants are exposed to information about the long-term benefits of preventing undernutrition than when they are only told about the short-term benefits, but the difference across information treatments is not statistically significant. Tests for balance across the two information treatment groups reveal that the treatment arms are well balanced across all variables.

OLS regression results are presented in table 6. The information treatment is not significant in the model, so women in the sample who are exposed to information about the long-term benefits of preventing undernutrition do not value LNS differently than women who are not exposed to this information. Among the individual characteristics included in the model, if a participant has previously used a nutrient supplement during pregnancy, her WTP for a day's supply of LNS is almost $0.05 higher ($p<.01$) than those who have not, which may be an indicator that women who are already familiar with nutrient supplementation during pregnancy are also more willing to pay for new supplements that become available. Other individual characteristics that we might expect to be related to WTP, including the participant's position in the household, age, level of education, and employment status, are not significant in the model

Among the household characteristics included in the model, participants who report a combined household income in the previous month of less than $65[17] have a $0.05 lower ($p<.01$) WTP for a day's supply of LNS than those within higher income categories, all else equal, reflecting the importance of a household's budget constraint in determining WTP. Also, the cost of transportation from the participant's household to the hospital where she receives prenatal care is significant and positively related to WTP at the 10% level. Women who face the highest transport costs are, in general, those who live the farthest from the hospital, so these women's choice to obtain prenatal care despite the high monetary and time costs may be an indicator of their commitment to a healthy pregnancy, which is also being reflected in a higher WTP for LNS.

Also included in the model are controls for the random market price of LNS determined in the practice rounds as well as the enumerators' rating of participant's comprehension of the auction process. All of these variables are positively and significantly related to WTP and are thus important to control for.

Repeat Purchase Behavior

Of the 115 participants in the auctions, 41 (35.65%) have used at least one coupon to purchase an additional week's supply of LNS after the auctions at the auction-specific market price. Table 7 presents the logit regression results. Except for the enumerator's rating of the participant's comprehension and the controls for the practice prices in the auction, all variables included in the WTP model are also included in the model of coupon usage. We also include an indicator of whether or not the participant purchased LNS in the auction, the participant's bid (WTP) from the auction, and the (auction-specific) market price for LNS. Since the estimated logit coefficients are not the marginal effects (Cameron and Trivedi 2005), we report marginal effects and change in predicted probabilities in table 8. For continuous variables we focus our discussion of the results on the marginal effect estimates, which are calculated at the mean of the regressors. For indicator variables, we focus on the change in probability estimates, which are calculated for a change in a specific indicator variable from zero to one with all other variables held at their mean value.

While the information treatment is not significant in the WTP model, here the effect of the information treatment is positive and significantly different than zero at the 10% level. The change in the probability of using a coupon to purchase LNS after an auction is 0.071 for participants who were told about the long-term benefits of preventing undernutrition relative to participants who were told only about the short-term benefits. Among the individual characteristics, the probability of using a coupon is 0.186 lower ($p<.05$) for household heads than women in other positions in their households, and the probability of using a coupon for LNS is 0.239 lower ($p<.01$) for participants who report being unemployed for a duration of at least the past 12 months. The household characteristics that are significantly related to the probability of using a coupon are the number of children under five and the cost of transport to the hospital. Participants from households with more children under five years have a lower probability of using a coupon, while higher transport costs from the participant's home to the hospital has a positive effect ($p<.01$) on the probability of using a coupon.

Another significant influence on the probability a participant redeems a coupon is whether she purchased LNS in an auction, where having purchased LNS increases the probability she redeems a coupon by 0.998 ($p<.01$). Similarly, the higher a participant's WTP from the auction (as indicated by her bid on LNS), the more likely she is to redeem a coupon. The market price for the LNS, which is both the price paid at the auction and the price to redeem the coupon, is not, however, statistically significant, though the negative sign on the marginal effect is expected.

Policy Implications and Conclusions

Household choices that influence maternal nutrition during pregnancy, such as the choice to invest in a nutrient supplement like LNS, may be influenced by the expected costs and returns to a particular prenatal investment as well as household preferences and constraints. This set of results suggest that although most people are willing to pay at least something for LNS, there is a fairly large range in the level of WTP, and the level of WTP varies significantly across some individual and household characteristics. If LNS proves to reduce the incidence of maternal undernutrition during pregnancy and improve the health and development of children, a successful transition from a controlled trial setting to a scaled-up, applied setting will hinge on devising effective distribution mechanisms and pricing schemes that take household characteristics, expectations, preferences, and constraints into account.

There are a number of policy implications that can be distilled from the results of the contingent valuation study and experimental auctions to inform the development of delivery options and pricing mechanisms for LNS. In particular, in order to successfully deliver LNS to women during pregnancy, it may be necessary for LNS to be distributed via multiple outlets with different pricing schemes, such as commercial food markets where LNS is priced relative to the cost of production and distribution and also prenatal care clinics where LNS is offered at a subsidized price by people trained in maternal and early childhood health. Commercial food market outlets may be an appropriate delivery mechanism for segments of the population with a higher WTP, like food secure households and households with relatively high per capita expenditures on food. For other segments of the population for whom WTP is lower, for example women who have never used a nutrient supplement during pregnancy or women from relatively food insecure households, delivery via prenatal clinics may be necessary to bolster demand, as health care providers can emphasize the role of nutrient supplementation in preventing undernutrition during pregnancy and the price of LNS may be set below the cost of production and distribution. In the same regard, prenatal clinics may be an important delivery outlet in terms of promoting consistent use of LNS, since our results show that women who are exposed to information about the long-term benefits of preventing undernutrition are more likely to make a repeat purchase, and prenatal clinics could be a dissemination point for such information. Finally, our results show that WTP is highest when food availability peaks and prices fall, highlighting the importance of considering seasonal variation in WTP, even among non-farming populations, when devising pricing and delivery mechanisms.

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Table 1. Variable Definitions and Summary Stats for Contingent Valuation Sample

Variable	Definition	Mean/ Frequency		Std Dev/ Percent	(Min, Max)
Female	=1 if respondent is female	Female:	298	65.56%	
		Male:	104	34.44%	
Age	Respondent's age		31.93	11.11	(18, 102)
Education	Respondent's years of education		8.38	3.64	(0, 16)
Unemployed	=1 if respondent has not worked in past 12 mos.	Yes:	37	12.25%	
		No:	265	87.75%	
Relative Discount Rate	Measure of individual discount rate		6.82	2.91	(0, 10)
Know Others Taking LNS	Number of people respondent knows (outside hh) who are taking LNS		0.17	0.46	(0, 3)
Children U5	Number of children under 5 in hh		0.53	0.66	(0, 3)
Unhealthy Pregnancy	=1 if respondent or other hh member has been undernourished during a previous pregnancy	Yes:	40	13.25%	
		No:	262	86.75%	
Daily Food Expenditures Per Capita	Per capita food expenditures per day in 2011 USD		1.25	0.88	(0.14, 6.53)
HFIA Score	Household Food Insecurity Access Score		3.04	4.44	(0, 19)
June	= 1 if questionnaire conducted in June	Yes:	22	7.28%	
		No:	280	92.72%	

N = 302

Table 2. Average Hypothetical WTP for Day's Supply of LNS (2011 USD)

	N	Mean (Std Error)	Std Dev	Min, Max	Zero Max WTP
Overall	302	0.559 (0.025)	0.432	0, 2.00	12 (4%)
Women	198	0.519** (0.031)	0.435	0, 2.00	12 (6%)
Men	104	0.634** (0.041)	0.419	0.07, 1.33	0

** Indicates max WTP is significantly different across men and women at 5% level

Table 3. OLS Regression Results for Hypothetical WTP

Variable	Coefficient	Robust Std Error
Female	-0.216***	0.059
Age	0.001	0.002
Education	-0.005	0.007
Unemployed	-0.139**	0.067
Relative Discount Rate	-0.004	0.008
Know Others Taking LNS	-0.015	0.064
Children U5	-0.064*	0.034
Unhealthy Pregnancy	0.088	0.076
Daily Food Expenditures Per Capita	0.011*	0.006
HFIA Score	-0.035***	0.007
Female*HFIA Score	0.035***	0.010
June	0.257***	0.090
N	302	
R-Squared	0.2230	

Significance codes: *** (p < .01), ** (p < .05), * (p < .1)
Note: Controls for starting bid and enumerator are also included in model (unreported)

Table 4. Variable Definitions and Summary Statistics for Auction Sample

Variable	Definition	Mean/ Frequency		Std Dev/ Percent	(Min, Max)
Information Treatment	=1 if respondent received information on long-term benefits	Yes:	52	45.22	
		No:	63	54.78	
Head	=1 if respondent is head of household	Yes:	15	86.96	
		No:	100	13.04	
Age	Respondent's age	27.94		6.64	(17, 44)
Education	Respondent's years of education	6.77		3.64	(0, 15)
Unemployed	=1 if respondent has not worked in past 12 mos.	Yes:	15	86.96	
		No:	100	13.04	
Children U5	Number of children under 5 in hh	0.77		0.75	(0, 3)
Unhealthy Pregnancy	=1 if respondent or other hh member has been undernourished during a previous pregnancy	Yes:	25	21.74	
		No:	90	78.26	
Used Supplement	= 1 if respondent has every used a nutrient supplement during pregnancy	Yes:	85	73.91	
		No:	30	26.09	
Low Monthly Income	= 1 if total household income was < $65 in the previous month	Yes:	29	25.22	
		No:	86	76.78	
HFIA Score	Household Food Insecurity Access Score	4.73		4.07	(0, 13)
Transport to Hospital	Amount paid for transport from home to hospital in 2011 USD	0.75		0.61	(1, 3.33)

N = 115

Table 5. Average Bid on Day's Supply of LNS (2011 USD)

	N	Mean (Std Error)	Std Dev	Min, Max	Zero Bids
Overall	115	0.261 (0.012)	0.124	0, 0.67	2 (1.74%)
Short-Term Benefits	63	0.247 (0.013)	0.102	0, 0.57	1 (1.59%)
Short- and Long-Term Benefits	52	0.278 (0.020)	0.145	0, 0.67	1 (1.92%)

Table 6. OLS Regression Results for Experimental Auction Bids

Variable	Coefficient	Robust Std Error†
Long-Term Benefits	-0.025	0.020
Household Head	0.011	0.035
Age	-0.001	0.002
Education	0.002	0.003
Unemployed	0.006	0.015
Used Supplement	0.049***	0.017
Children U5	0.013	0.019
Unhealthy Pregnancy	-0.037	0.036
Low Monthly Income	-0.052***	0.017
HFIA Score	-0.002	0.002
Transport to Hospital	0.024*	0.014
LNS Practice Price 1	0.522***	0.186
LNS Practice Price 2	0.380***	0.073
Comprehension	0.035*	0.018
N	115	
R-Squared	0.3804	

Significance codes: *** ($p < .01$), ** ($p < .05$), * ($p < .1$)
†Errors are clustered at the auction level
Note: Controls for enumerator are also included in model (unreported).

Table 7. Logit Regression Results for Coupon Redemption

Variable	Coefficient	Robust Std Error†
Long-Term Benefits	1.166*	0.716
Household Head	-1.940**	0.976
Age	0.063	0.059
Education	0.042	0.093
Unemployed	-3.097***	1.089
Used Supplement	1.117	0.794
Children U5	-0.734**	0.371
Unhealthy Pregnancy	0.717	0.745
Low Monthly Income	0.639	0.858
HFIA Score	0.137*	0.081
Transport to Hospital	1.560**	0.708
Purchased LNS in Auction	7.885***	2.172
WTP for LNS	15.664***	5.015
Market Price of LNS	-2.417	4.018
N	115	
Pseudo R-Squared	0.5624	
Log Pseudo-likelihood	-32.778	

Significance codes: *** ($p < .01$), ** ($p < .05$), * ($p < .1$)

†Errors are clustered at the auction level

‡Marginal effects are evaluated at the mean of the dependent variables.

Table 8. Marginal Effects and Percent Change for Coupon Redemption

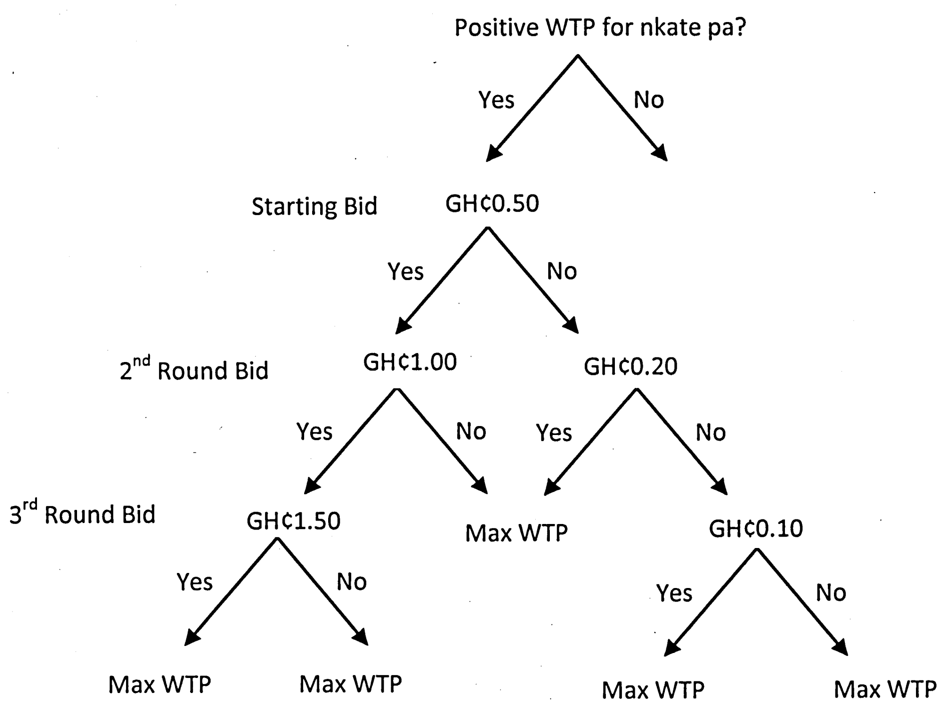
Variable	Marginal Effect	Std Error†	Change in Probability‡
Long-Term Benefits	0.176*	0.096	0.0711
Household Head	-0.293**	0.145	-0.1861
Age	0.009	0.007	0.0094
Education	0.006	0.014	0.0064
Unemployed	-0.467***	0.183	-0.2389
Used Supplement	0.169	0.123	0.1428
Children U5	-0.111*	0.066	-0.111
Unhealthy Pregnancy	0.108	0.117	0.1221
Low Monthly Income	0.096	0.135	0.1061
HFIA Score	0.021	0.013	0.0206
Transport to Hospital	0.235***	0.082	0.2372
Purchased LNS in Auction	1.190***	0.232	0.0135
WTP for LNS	2.364***	0.504	0.9982
Market Price of LNS	-0.365	0.618	-0.3687

Significance codes: *** ($p < .01$), ** ($p < .05$), * ($p < .1$)

†Errors are clustered at the auction level

‡For indicator variables, Change in Probability is the change in the predicted probability of redeeming a coupon as x changes from 0 to 1 with all other variables held at their mean. For continuous variables it is the change in predicted probability as x changes from ½ unit below the mean to ½ unit above the mean with all other variables held at their mean.

Figure 1. Sample Bidding Tree



[1] Low birth weight at term is defined as completing at least 37 weeks of gestation and weighing less than 2500g at birth (Black et al. 2008).

[2] A child is considered stunted if his/her height-for-age is at least 2 z-scores under the international reference (The World Bank 2006).

[3] Body mass index is calculated as weight in kilograms over height in meters squared (BMI = kg/m^2). A BMI below 18.5 is considered low.

[4] The hypothetical WTP study and experimental auctions are ongoing, and target sample sizes have not been reached. All empirical results will be updated with the full samples as soon as they are available.

[5] A newborn who has completed at least 37 weeks of gestation and has a birth weight of less than 2500g is referred to as Intrauterine Growth Restriction – Low Birth Weight (IUGR-LBW) (Allen and Gillespie 2001).

[6] The model could be extended to include future periods in the child's lifecycle, but this two-period framework sufficiently captures the implications of the inter-period connectedness between health and human capital.

[7] Ultimately, approximately 520 households will be randomized into the hypothetical WTP study, or approximately 60% of the total iLiNS study sample size of 864.

[8] The dichotomous choice question is, "If you went to the new kiosk today and the owner quoted you a price of GH¢ X for 1 sachet of nkate pa, which is 20 grams, would you purchase it, bearing in mind your income and daily expenses?"

[9] To determine whether the respondent receives rice in a week or a month, s/he rolls a die. If the number rolled is smaller than the amount of rice measured, the tin of rice is delivered to the respondent in a week, and if the number rolled is equal to or greater than the amount of rice measured, the tin of rice plus the amount measured is delivered to the respondent in a month. The quantity of additional rice measured by the respondent serves as his/her individual discount rate relative to the rest of the sample.

[10] In general, ordinary least squares (OLS) estimates of censored data are inconsistent because the conditional mean of censored data differs from that of uncensored data (Cameron and Trivedi 2005). As a result, WTP data is often estimated using a tobit maximum likelihood estimator (Lusk and Shogren 2007), which is consistent under the assumption that the errors are normally distributed and homoskedastic. If these assumptions are violated, however, tobit estimates are inconsistent. Using lagrange multiplier tests based on the tobit generalized residuals and scores to test these assumptions with our hypothetical WTP data, the assumptions of normality and homoskedasticity are both strongly rejected ($p < .01$) (Cameron and Trivedi 2010).

[11] The difference in WTP across treatment arms of the efficacy trial will also be evaluated. This analysis is not included in this article because the efficacy trial is still ongoing and researchers are blind to the treatment assignments.

[12] The decision to conduct the auctions with people not participating in the iLiNS study was based the fact that some of the iLiNS study participants are receiving LNS for free as part of the study and would therefore not have an incentive to buy it and because we did not want to introduce LNS into households randomized into the non-LNS arms of the study.

[13] The BDM auction procedure is explained to participants following a story-line in which a trusted friend is going to a nearby market, and the participant wants the friend to purchase the auction item for them at the market but does not know the market price. If the friend discovers the market price is higher than the amount of money sent by the participant, the friend will not purchase the item and will return the participant's money. If the amount of money sent by the participant is at least as much as the market price, the friend will purchase the item at the market price and return any remaining balance to the participant.

[14] To minimize the effect of the practice auction prices on participants' real bid for a week's supply of LNS, during the practice auctions participants are exposed to a range of pre-selected potential prices their friend might discover as the price of LNS at the market. Participants are told directly that the potential prices should not influence how much LNS is worth to them.

[15] We model WTP using a logit specification over a probit specification based on a comparison of the log likelihoods (Cameron and Trivedi 2009). The log likelihood is 1.26 higher for the logit than the probit specification.

[16] Participants bid on a week's supply (7 sachets) of LNS. These bids were divided by 7 prior to calculating the summary statistics and running the regressions in order to make the bids comparable to the hypothetical WTP, which was stated for a day's supply of LNS.

[17] Participants were asked which bracket, among five income brackets, best described their total combined household income in the previous month.