Experimental Markets for Micronutrient Supplements to Prevent Undernutrition: Estimating Household Demand Persistence in Rural Burkina Faso

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Abstract

The success of Plumpy'Nut® in treating severe acute malnutrition revolutionized the treatment of malnutrition and sparked efforts to develop Lipid-based Nutrient Supplement (LNS) products aimed at *preventing* undernutrition. The move from therapeutic to preventative LNS products has fundamental implications for supply chains and implies that private demand and the private sector will likely play central roles in the distribution of these products. We use experimental markets in rural Burkina Faso to shed light on household demand for preventative LNS and explore associated product distribution challenges. We conducted experimental auctions for a 'small quantity' (SQ) LNS product to gauge initial demand. Then, in collaboration with local vendors, we conducted a year-long market trial in 14 villages that enabled us to test the effect of both price and non-price factors on the persistence of household demand. We find that price elasticity of demand for these supplements is high on average (-5), but that persistent demand is significantly more price sensitive (-8) than first-time purchases (-2.4). We also find that a loyalty card that offers a small reward for a month of purchases strongly boosts persistent demand. Both the price and non-price demand effects diminish after a few weeks, however. Even when SQ-LNS products or other micronutrient products are cost-effective as an investment in early childhood health, our results suggest that private demand may cover less than half the production and distribution costs, underscoring the need for innovative supply chains and hybrid private-public delivery strategies.

Keywords: Undernutrition; Early childhood; Micronutrients; Supplementation; Demand; Burkina Faso.

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1 Introduction

In the past decade, a fortified peanut butter-based product called Plumpy'Nut® has seen remarkable success as a treatment for severe acute malnutrition (SAM) among young children. This success has been showcased widely in popular media outlets worldwide and prompted several companies to formulate similar energy-dense products that also provide micronutrients and essential fatty acids in a lipid-based paste (typically, peanut paste) – products collectively known as Ready-To-Use Therapeutic Foods (RUTF) or 'large-quantity' Lipid-based Nutrient Supplements' (LNS). Rigorous evidence of the success of LNS products in treating SAM (Ciliberto et al., 2005; Diop el et al., 2003) triggered a massive budgetary shift towards therapeutic LNS products by the three major childhood nutrition players: United Nations Children's Fund (UNICEF), *Médecins Sans Frontières* (MSF) and the World Food Programme (WFP).

This unprecedented success, coupled with increasing recognition of undernutrition as a top global health and economic development priority, has stimulated the emergence of a globally-recognized, coordinated framework for addressing undernutrition. At its center, the Scaling Up Nutrition (SUN) movement advocates multi-sectoral strategies to reduce undernutrition as complements to direct nutrition interventions such as therapeutic feeding, food fortification, micronutrient supplementation, and breastfeeding promotion (Nabarro et al., 2012; Scaling Up Nutrition, 2012). While the revolutionary role of RUTF in treating SAM is clear, relatively recent advances in the understanding of the irreversible, long-term deleterious effects of undernutrition has spawned broad recognition of the need to not only treat children suffering from SAM but also prevent undernutrition during the critical first 1,000 days of life (Arimond et al., 2013). Sustainable, long-term strategies to prevent undernutrition, including largely invisible micronutrient deficiencies described as 'hidden hunger', will likely be primarily food-based (e.g., dietary diversification and fortification) (von Grebmer et al., 2014). In the short-term, however, supplementation can help meet the high nutrient requirements of pregnant and lactating mothers and of children from 6-24 months of age (Arimond et al., 2013; Dewey and Vitta, 2012).

Within this context and fueled by a mix of public and private R&D investments, a decade of innovation has led to the emergence of three distinct and differentiated LNS product classes (see Table 1). 'Large-quantity' LNS such as Plumpy'Nut® are designed to provide 100% of a (9-12 month old) child's energy demands outside breast milk. 'Medium-quantity' LNS products (also known as Ready-to-Use *Supplementary* Foods (RUSF)) aim to treat moderate malnutrition and prevent SAM, and are designed to be combined with other complementary foods and therefore provide 50-100% of energy demands. 'Small-quantity' LNS products (SQ-LNS) aim to prevent undernutrition and promote normal growth and are designed to provide <50% of energy demands. While the LNS product classes described in Table 1 may seem like different points on a continuum of formulations – a continuum created by simply dialing up or down different ingredients and ration sizes – some of these differences bring major supply chain implications. In this paper, we use experimental markets for SQ-LNS in rural Burkina Faso to shed light on these challenges and explore the associated implications for distribution.

The supply chain challenges we study stem from differences in how and why these nutritional products are consumed. Large-quantity LNS products are designed to be consumed intensively by children as part of a short-term emergency treatment regimen and are exclusively distributed via public channels. Indeed, in many countries, including Burkina Faso, it is illegal for individuals to buy or sell these products privately. In contrast, SQ-LNS products are designed to be consumed daily for extended periods of time to compensate for the lack of micronutrients and essential fatty acids, and hence guard against undernutrition. Key beneficiaries of these products are expected to be young children (aged 6-24 months), and pregnant and lactating women.

These differences in objectives and consumption protocol have profound implications for supply chains, as suggested by Table 1. Whereas major public and private players have structured large- and medium-quantity LNS supply chains and helped coordinate purchases and delivery of products among nutrition stakeholders in the public, non-profit and private sectors, they are unlikely to take the lead with SQ-LNS products for which demand is less certain, acceptable product specifications have not yet been agreed upon, and cost-effectiveness has not been systematically demonstrated (Lybbert, 2011). Instead, any coordination of stakeholders and supply chains will likely emerge from a mix of public and private sector engagement. Where and how such a hybrid distribution system emerges will reflect a host of site-specific factors, including nutritional needs, private sector presence and capacity, public health and other infrastructure, and public sector commitments to providing necessary investments and coordination.

The potential evolution of SQ-LNS supply chains hinges critically on household demand for these products in the broader context of household food, nutrition and health choices. We all periodically struggle to make important preventative health investments (which is why we see wisdom in the words of Benjamin Franklin, "an ounce of prevention is worth a pound of cure"), but these struggles may be even more pronounced among the poor as a thriving literature in development economics documents (Dupas, 2011; Meredith et al., 2013). Understanding the nature of SQ-LNS demand sets the stage for designing, testing and scaling up delivery options. Specifically, by shaping which households purchase these products, how and how regularly children consume them, and how these consumption patterns translate into real health benefits private demand for SQ-LNS products will determine the viability and sustainability of hybrid public-private options for delivering daily supplements to the urban and rural poor. Household demand for these products thereby creates or constrains opportunities to leverage the comparative advantage and resources of public organizations and private firms.

This study is part of a broader International Lipid-Based Nutrient Supplement research program, and more specifically the iLiNS-Zinc nutrition trial in rural Burkina Faso that measured, among other things, the effects of an SQ-LNS product formulated for young children on their growth and development. Analysis of these clinical trial results show that these SQ-LNS products, when provided with monitoring and treatment of malaria and diarrhea to children from 6-18 months of age, improve linear growth, decrease the prevalence of both stunting (length-for-age z-score < -2) and wasting (weight-for-length z-score < -2), and positively affect some aspects of cognitive and behavioral development (Hess et al., 2013). As part of this project, we used experimental methods to measure private demand for SQ-LNS. In mid-2013, we designed and conducted experimental auctions for SQ-LNS in 14 villages in our study area. These auctions, which included some households that participated in the iLiNS-Zinc nutrition trial but primarily consisted of other (non-iLiNS-Zinc) households with children in the target age range (6-24 months), enable us to estimate complete, incentive-compatible demand curves for SQ-LNS, and to explore the determinants of demand heterogeneity. Immediately after conducting the auctions, we launched a market trial in the same 14 villages. The structure of this market trial allows us to estimate the price elasticity of demand for SQ-LNS overall, as well as for initial and repeat purchases separately. Subsequent phases of this market trial enable us to estimate the effect on demand of a loyalty card that offers a small reward to households that purchase a month's worth of SQ-LNS, including the gender-differentiated effects of this loyalty card.

We make two primary contributions in this analysis, which builds on a thriving area of inquiry in development economics. We provide the first rigorous evaluation of persistent demand for a nutritional supplement in a developing country. We find that price elasticity of demand for SQ-LNS is high on average, but that elasticity for repeat purchases is significantly higher than for initial purchases. This has important implications for delivery design for SQ-LNS and other nutrition investments that require daily (or at least regular) consumption. In addition, even if SQ-LNS is cost-effective as a nutritional investment, private demand may cover less than half the production and distribution costs of SQ-LNS, suggesting the need for mixed private-public delivery strategies. Second, we estimate the impact of a non-price factor on demand persistence. The estimated impact of this loyalty card on demand persistence enables us to directly compare price and non-price determinants of demand, which set the stage for thoughtful discussions about possible hybrid delivery strategies that involve both public and private sectors.

2 Background

2.1 Micronutrients and Human Development

The first 1,000 days in a child's life, beginning at conception and extending through his/her second birthday, have been identified as *the* critical window for preventing undernutrition (Black et al., 2013). Due in part to rapid growth and development, nutritional needs are very high in a child's first 1,000 days, and undernutrition during this vulnerable period increases the risks of morbidity and mortality, growth faltering, and impair motor and cognitive development (Dewey and Begum, 2011; Martorell, 1999; Victora et al., 2010). The long-term implications of early-childhood undernutrition can include shorter adult stature, deficits in schooling, lower economic productivity, and decreased offspring birthweight (Hoddinott et al., 2013; Martorell et al., 2010; Victora et al., 2008). Beyond the moral imperative to provide children with adequate nutrition to thrive throughout their life-course, then, economic development hinges in many ways on improving maternal and early-childhood nutrition (Alderman, 2010; Alderman and Behrman, 2006).

While a food-based approach to improving dietary quality through increased consumption of nutrient-rich foods is generally acknowledged as the preferred long-term solution to undernutrition, strategies that involve fortification and/or supplementation can be implemented in the short-term and help meet high nutrient needs of very young children during the period of complementary feeding from 6-24 months of age (Dewey and Vitta, 2012). Fortified food blends that have been specifically formulated for young children represent one such option, but concerns about breastmilk displacement, high variability in the amount of the product (and therefore the quantity of nutrients) consumed, and the limited dietary diversity associated with relying on a single food has sparked the development of micronutrient powders and SQ-LNS, both intended for home fortification (Dewey and Vitta, 2012). Compared to micronutrient powders, which contain only micronutrients and are intended to be added to food just prior to consumption, SQ-LNS products embed these micronutrients in a peanut base and deliver energy, protein, and essential fatty acids and key macrominerals not contained in micronutrient powders (Arimond et al., 2013). Moreover, the fat content of the peanut paste may enhance the bioavailability and absorption of fat-soluble vitamins (Dewey and Vitta, 2012).

While we have learned much in recent decades about key dimensions of child nutrition, important limitations to our understanding persist – limitations that are important caveats in this field and to this specific analysis. Child growth and development are complex processes (Black et al., 2013), and the individual and collective effects of the three general stressors to these processes (undernutrition, infections and disease) are not completely understood (Hendrix 2010) and may well be household- or even individual-specific (Dewey and Adu-Afarwuah, 2008). Many key issues related to undernutrition remain uncertain or unknown: the definitions of undernutrition are hard to make concrete even for some of the basic nutrients (e.g. vitamin A), the effects of shortfalls of particular nutrients are hard to predict even in controlled settings, the effects of shortfalls of collections of nutrients are essentially unknown, and the detailed nutritional status of children in developing countries is rarely known (for an exception, see (Engle-Stone et al., 2012).

2.2 Health Investments and Behavioral Biases

The literature on the demand for preventative health and nutritional products in developing countries makes it clear that despite high private returns, household adoption of and willingness to pay for many preventative products is often quite low (Dupas (2011)provides an overview). The persistence of this phenomenon across many different preventative products, including insecticide-treated bednets, water filtration systems, improved cook stoves, and immunizations, has primarily been explored in the context of liquidity constraints (e.g., Beltramo et al. (2014); Meredith et al. (2013); Tarozzi et al. (2014)) and a lack of information about health risks and potential returns to prevention (e.g., Beltramo et al. (2014); Ashraf et al. (2013); Meredith et al. (2013); Chowdhury et al. (2011)).

Even with the provision of information and/or free or highly subsidized distribution of preventative health products, adoption and use rates over the long-term often remain low (Thurber et al., 2013). Beyond information and financial constraints, there may be other household-level behavioral considerations that play an important role in a household's decision to adopt and/or regularly use a preventative health product. These include framing effects, present bias, zero price effects, social norms, and loss aversion (Buttenheim and Asch, 2013; Dupas, 2011). Preventative investments in products like SQ-LNS that require regular purchases and high frequency usage demand consistent decisions that can only be sustained in the long-run by the formation of usage habits that reduce the demands on scare attention (Banerjee and Mullainathan, 2008; Dupas et al., 2013; Mullainathan and Shafir, 2013; Shah et al., 2012).

Several platforms, including markets, can potentially deliver micronutrient products to vulnerable populations via interventions in agriculture, health and social-protection (Olney et al., 2012). Scant evidence exists on household-level demand for micronutrient supplements via market-based delivery mechanisms. A cluster-randomized controlled trial in Western Kenya monitored the sales of the micronutrient powder known as Sprinkles over a 12-month period (Suchdev et al., 2013). Sold by local vendors for approximately $0.027 per daily sachet as a component of an integrated health promotion and income-generating program, the study estimated the sales of Sprinkles led to an average intake of .9 sachets per week per child age 6-59 months. The study also found lower rates of iron and vitamin A deficiencies in villages where Sprinkles were marketed and sold. In another effort to monitor sales of a micronutrient powder, the ongoing evaluation of BRAC's Bangladesh Sprinkles Program, in which BRAC has partnered with the Global Alliance for Improved Nutrition (GAIN) and a local pharmaceutical company to produce and sell Sprinkles via a network of community health workers, may also contribute to the understanding of household demand for a preventative, supplementary product.

2.3 iLiNS-Zinc Project in Burkina Faso

The data used in these analyses were collected in close collaboration with the iLiNS-Zinc clinical nutritional trial of SQ-LNS products. The trial was conducted in 34 communities in a large corridor north of Bobo-Dioulasso in the south-western corner of Burkina Faso. Randomization was done at the community and concession (i.e., family compound) level. First, communities were stratified by selected indicators (population size; proximity to road and Bobo-Dioulasso; and health clinic affiliation) and then randomly assigned within strata into treatment communities (25) and control communities (9).[1] Children who met the inclusion criteria in the treatment communities were then randomly allocated to one of four intervention arms for 9 months (from 9 to 18 months of age): 1) SQ-LNS without zinc and placebo tablet (LNS-Zn0); 2) SQ-LNS with 5 mg zinc and placebo tablet (LNS-Zn5); 3) LNS with 10 mg zinc and placebo tablet (LNS-Zn10); or 4) SQ-LNS without zinc and 5 mg zinc tablet (LNS-TabZn5). Children in the control communities did not receive SQ-LNS or tablets from 9 to 18 months of age, but received SQ-LNS from 18 to 27 months after the data collection was finished. Enrollment of the rolling sample continued for approximately 11 months.

A weekly ration of SQ-LNS was delivered initially to participating children in plastic pots containing 140g (sufficient for one week). The child's caregiver was provided with a measuring spoon and advised to feed the day's allotment (20g = 2 spoons) in two separate servings at mealtimes. After 13 months of

[1] Treatment communities received SQ-LNS interventions at the outset of the study; control communities received SQ-LNS after the study had ended.

project implementation, the packaging changed and children received seven sachets containing 20g each per week; caregivers were instructed to feed their children one sachet/day, mixed with food at mealtime. The SQ-LNS for each treatment group were identical, except for their zinc content. Zinc tablets were water-dispersible and contained 5mg zinc or an identical placebo. The caregivers were advised to provide the tablet once daily, dissolved in water or breast milk, but not with other foods. Caregivers were given brief child feeding advice at enrollment, which included the above described instructions for SQ-LNS and tablets and the recommendation to continue breastfeeding and to provide a large variety of foods.

3 Research Design and Data

Within the iLiNS-Zinc project described above, we designed a series of research activities to evaluate households' valuation of SQ-LNS in order to shed light on essential supply chain and delivery implications. Specifically, we conducted three different phases of SQ-LNS demand assessment. First, we elicited hypothetical WTP from households participating in the iLiNS-Zinc project during a broader set of socio-economic data collection activities. Second, we conducted experimental auctions with a mix of iLiNS and non-iLiNS households in our study area to elicit incentive-compatible experimental WTP (eWTP). Finally, we used the auctions as a platform for launching market trials in which we enlisted the help of local vendors to make SQ-LNS available in 14 villages within our study area. In this paper, we briefly describe and analyze the data from the experimental auctions and focus primarily on the market trial with local vendors.

One important dilemma in these demand assessment phases, what information to provide rural households about SQ-LNS and how to convey it, merits some attention. The broader iLiNS-Zinc project was designed to rigorously evaluate the impact of SQ-LNS on health outcomes of children. Since these demand elicitation activities occurred over the course of these nutritional trials, our research team was quite constrained when drafting the scripts to be used and in developing placards and other promotional materials that were used for the SQ-LNS market trial. Using language that was carefully crafted so as to not over-state what we knew about the benefits of SQ-LNS products, we informed participants in all three demand phases that (1) average diets of children in the area are deficient in one or more of the micronutrients that nutritionists believe are important for child growth and development and (2) the SQ-LNS product described/offered to them contain all of the micronutrients that nutritionists believe are needed for children to grow and develop according to their genetic potential.

3.1 SQ-LNS Auction

Building on the first phase hWTP demand elicitation, we conducted a series of experimental auctions for SQ-LNS in 14 villages in the iLiNS-Zinc study area during a four week period in mid-2013. The auction sessions were composed of fathers and mothers (N=505) of children in the target age range (6-24mo), most of whom did not previously participate in the iLiNS-Zinc trial. Auction participants were recruited via town crier the day before and the day of the auction. The crier announced the iLiNS team was in the village and wanted to speak with mothers and father of children age 6-24 months. Potential auction participants were screened for eligibility, and then eligible and willing participants received a participation fee (double the local daily wage rate) and were given some basic information about SQ-LNS and its potential benefits.

Participants were then given an opportunity to purchase a week's supply of SQ-LNS for their children. WTP was elicited using a discrete version of the Becker-DeGroot-Marschak (BDM) mechanism in which participants were asked if they would be willing to pay specific, incrementally-increasing prices for a week's supply of SQ-LNS. Once a participant indicated s/he would not be willing to pay a specific price, his/her maximum WTP was recorded as the previous price in the series, and the participant purchased SQ-LNS if his/her maximum WTP was at least as high as a (subsequently revealed) 'market' price.

Because the efficacy of LNS depends on regular consumption throughout early childhood, we also asked a series of follow-up questions about WTP in the long-term. Specifically, we asked if a participant would pay his/her maximum WTP for LNS each week until his/her child was 24 months. The price was then increased/decreased in small increments until the participant changed his/her answer. By jointly analyzing parents' incentive-compatible eWTP for LNS with anthropometric, demographic and economic data, we are able to begin to explore the determinants of demand.

Table 2 includes descriptive statistics of variables collected during these auctions. Principal component analysis was used to combine household ownership of a set of assets[2] into an asset index (Vyas and Kumaranayake, 2006). Food security data were collected using an abbreviated version of the Household Food Insecurity Access Scale developed by USAID's Food and Nutrition Technical Assistance (FANTA) project (Coates et al., 2007). Each household received a food security score between 0-15 based on how frequently the household experienced each of five food insecurity conditions in the past four weeks, where higher scores indicate higher levels of food insecurity.

Figure 2 depicts individuals' valuation for SQ-LNS as demand curves. The solid line in this graph is constructed based on individuals' incentive-compatible WTP for a week supply of SQ-LNS. It is truncated at the maximum price on the price list used in the auction (~$1.20). The dashed line is constructed based on individuals' open-ended stated WTP for SQ-LNS for regular purchases for the 18 months of recommended usage (6-24 months of age). Although this is not incentive compatible, we believe this long-term WTP is useful because it was elicited immediately following the auction for a week supply. The comparison of the two curves suggests that persistent demand for SQ-LNS is roughly 40% lower than demand for a single week supply. For example, whereas 50% of participants were willing to pay $1 or more for a week supply, only 30% claimed to be willing to pay this amount consistently over 18 months of usage.

3.2 SQ-LNS Market Trial with Vendors

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[2] The set of assets used in the construction of the asset index are mattress, radio, TV, cellular phone, bed, bicycle, moped, stove, and solar panel.

We designed a market trial as the final test of private demand for SQ-LNS. This market trial was conducted in the same 14 villages that hosted experimental auctions for SQ-LNS. It launched immediately following the experimental auctions in each village and was announced to auction participants at the conclusion of each session (e.g., “Beginning next week, you will be able to purchase SQ-LNS at Abdul’s shop on the corner between the mosque and the market.”)

The primary objective of this market trial was to rigorously evaluate the persistence of demand for SQ-LNS in a naturally-occurring market setting familiar to households in our study area. For this purpose, we engaged one or more local vendors[3] in each village as collaborators (32 vendors in all) and used a contract to establish the terms of the collaboration, including a small commission the vendor would receive for each sachet they sold. Each vendor was given a placard that included information about how it is to be consumed and its potential benefits along with an initial inventory of SQ-LNS. They were also given a lockbox to collect payments for the product and were told that they could only sell sachets to customers with special voucher booklets. Each sale was registered using a slip from these booklets: Vendors would write the number of sachets sold and the date and put the slip into the lockbox with the cash paid by the customer. Voucher booklets were distributed to all iLiNS households and auction participants. Three extra booklets were given to iLiNS households – booklets they were encouraged to distribute to friends. Vendors were also given booklets to keep on hand for interested customers who had not yet received a voucher booklet. Using a unique, household-specific code on each voucher booklet, we are able to track purchases over time. Once each week members of our field research team (would-be ‘sales reps’) would visit each vendor, collect payments and voucher slips, reconcile the money collected and product sold, refresh the vendor’s inventory, and calculate and pay him his commission.

This market trial was implemented in three separate phases. In phase one, we randomly assigned seven of the villages to a low price treatment and the other seven to a high price treatment. For improved statistical power, we used a ‘matched pair randomized cluster’ (MPRC) approach in which villages were paired based on observable demand and market characteristics before randomly assigning the low price to one village in each pair and the high price to the other. To match villages in this MPRC approach, we exploited baseline census data, market characteristics data, and detailed socio-economic data that were collected in the broader iLiNS-Zinc project. Specifically, we selected six matching variables to capture features of demand and market size that are relevant to SQ-LNS: village population, distance from village to paved road, village mean asset index, village mean food insecurity score, mean number of shops per village, and the share of households that had heard of Plumy’Nut® prior to the beginning of the project in 2009. These six matching variables were used to construct a factor analytic matching

[3] We explored the option of using other outlets in addition to (or even instead of) local vendors. For example, health clinics and pharmacies might make sense as outlets for SQ-LNS. We settled on concentrating only on local vendors as this would ensure the most widespread access to SQ-LNS: every village has at least one permanent (even if very small) shop.

index. Finally, we paired villages with their nearest neighbor in terms of this index.[4] With the village pairs formed, a simple coin toss determined which of these villages (vendors) would sell SQ-LNS at the low price (150 CFA/seven-sachet strip; $0.30) and which would sell at the high price (300 CFA/seven-sachet strip; $0.60).[5] Figure 1 includes a map of these 14 villages that indicates the village pairings and the random price assignment. Phase one of the trial was launched in July 2013.

In phase two of the trial, we reduced all high prices to 150 CFA/strip so that a single, uniform price prevailed across all 14 villages and 29 vendors. Comparing purchases in this phase with those in phase one provides a 'within' village angle on price sensitivity of demand. It also enables us to analyze the dynamics of market demand in these villages by, among other things, contrasting responses on the intensive margin (current clients increasing purchases) and the extensive margin (new clients entering the market). Phase two the trial was launched after week 17 of the trial.

Finally, in phase three of the market trial we introduced an individual-level non-price randomization. We conducted a series of promotional sessions on market day in each of the 14 villages. These sessions informed caretakers of target age children about the use, availability and potential benefits of SQ-LNS using a format common in the region. Large groups congregated around the loud speakers and project team. An entertaining member of the project team provided some basic information about the product and then led a question-answer interaction with the crowd. To ensure representation from both male and female caretakers from target households, we actively recruited parents of young children. This was followed by a popular prize wheel for participants who cared for target age children, often including two members of the same household (e.g., a mother and father). Each person spinning the wheel had equal chances of winning a small, medium or large prize. The small prize consisted of a free strip of 7 SQ-LNS sachets. The medium prize consisted of a promotional hat and t-shirt. The large prize consisted of the hat and shirt and a product loyalty card that enabled the recipient to redeem 28 empty SQ-LNS sachets for a small reward (maximum of four rewards). We took photos of the loyalty card winners so we could verify their identity at the time of redemption and gave them a sachet hook for collecting empty sachets and a menu of reward options.[6] Phase three of the trial was launched in weeks 32-34 of the trial and concluded in August 2014.

We provide several figures to graphically depict the data collected during this market trial. Even though we observe the precise date of all purchases, because most of these purchases involve seven sachet

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[4] To get unique pairs, we used an iterative process in consultation with our field manager. The final pairings are based on three first-order matches (nearest neighbors), one second-order match, one third-order match, and two fourth-order matches.

[5] Based on current production technologies and input prices in Niger, even this 'high' price does not cover all production costs or the likely mark-up required by vendors. Cost-cutting innovations may help to close this gap, but is unlikely to close it entirely, which underscores the need for some level of public support or subsidization to ensure sufficient consumption of SQ-LNS to generate the expected growth/development benefits, if broad-based provision/promotion of SQ-LNS products becomes part of rural nutrition/health programs in rural Burkina Faso.

[6] These options included familiar items in local shops such as powdered milk, Nescafé, and soap. The items were selected to be worth approximately 150CFA each.

strips (see Figure A1) we aggregate these purchases into weekly time steps throughout most of the analysis. Figure 3 shows the total number of sachets purchased from our 29 vendors during phase one of the trial (i.e., the first 17 weeks). This figure shows a pronounced price effect on total purchases and (especially) on repeat purchases (i.e., purchases after a household's first SQ-LNS purchase). Figure 4 shows the progression of demand over the course of all three phases of the trial. The top panel shows a measure of demand that is normalized by the estimated number of target age children in the 14 villages included in the trial. This measure of demand – which provides a crude proxy for 'community compliance' – indicates the average number of SQ-LNS sachets purchased in a community for each target child in the community. The natural benchmark for this measure is one sachet per child per day (the product was developed to meet daily needs), which would in principle imply complete compliance. The bottom panel in this figure has a similar pattern in a closely related demand measure: the number of households choosing to purchase at least seven sachets each week. The effect of the high initial price on repeat purchases during phase one of the trial is clearly evident in this figure.

Next, Figure 5 depicts the relative share of purchases by voucher source. Using the unique voucher codes, we are able to track purchases and thereby know how each consumer received their voucher booklet. Overall, the bulk of the purchases are made by those who received booklets from friends of iLiNS households. While there are some patterns across village pairs (e.g., in the share of purchases by vendor-distributed booklets), there are no discernible patterns by low-high price.

Since it is formulated as a daily supplement, one of the crucial demand aspects for SQ-LNS is the consistency of demand over time, which we refer to as demand persistence. Before moving to more in depth analysis of these data, we construct cumulative distribution functions to depict this important demand dimension. These cumulative distribution functions (in Figures 6 and 7) suggest that while price does appear to have a significant effect on demand persistence, even households with access to SQ-LNS at the low price rarely purchase seven or more sachets per week for more than two weeks in a row.

3.3 Accompanying Household Data

In order to characterize household demand for SQ-LNS using these auction and market trial data described above, we need to know something about these households. We collected these data from different households at different times depending on their participation in the study. For those participating in the clinical nutritional trial of the iLiNS-Zinc study – in either a treatment or a control arm – we collected detailed socioeconomic data at the individual, household and concession levels at enrollment and again at the project endline (when enrolled children completed the treatment regime, at 18 months of age). In addition, upon enrollment, a subsample of approximately 30% of the households from each trial arm was randomly selected to participate in several in-depth socioeconomic studies. In these households, questionnaires were administered to either the male head of household or to the child's primary caregiver (respondent was randomly pre-selected at enrollment).

For those who participated in the experimental auction, we collected basic household and individual data before or after the auction session. These household data are less detailed than the enrolment and endline data that were collected in the nutritional trial, but nonetheless allow us to characterize basic demographic and economic features of these households. The majority of the households represented in this study participated in neither the nutritional trial nor the auction. Instead, they enter our data by purchasing SQ-LNS using a voucher booklet that they received from a friend who participated in the nutritional trial or directly from one of our vendors. In order to maintain the most natural market setting for the market trial, we opted not to contact these households for the duration of the trial. Throughout the market trial therefore our only link to these households was via their voucher code, which indicated their village of residence and pattern of SQ-LNS purchases but nothing more. At the conclusion of the market trial, we randomly sampled households with voucher booklets – stratified by intensity of demand over the course of the trial – and conducted a detailed socioeconomic survey.

4 Analysis and Results

4.1 Determinants of Demand in SQ-LNS Auction

To estimate the determinants of demand for a week's supply of SQ-LNS, we model WTP as a function of a set of participant and household characteristics, including demographic, economic, and anthropometric variables. As a result of the discrete choice version of the BDM mechanism employed in our auction, WTP is censored from above at the highest price in the price series, so we use the Tobit maximum likelihood estimator to obtain our model parameters. Although the series of auction sessions were designed to be as similar to one another as possible, small differences across sessions due to factors such as the composition of men and women, questions that arose during a session, or other session-specific factors could lead to correlation in bids among participants in a particular session. To account for this, standard errors are clustered at the auction session level (Cameron and Miller, *Forthcoming* 2015). Results are presented without and with auction session fixed effects in specification one and two, respectively, of Table 3.

As previously described, during the auction sessions we also elicited hypothetical WTP for a week's supply of SQ-LNS continuously until the youngest child in the household reaches age 24 months. The determinants of this 'long-term' WTP are modeled using OLS, and the results with and without session fixed effects are reported in specifications three and four of Table 3.

Across both specifications one and two in Table 3, WTP for a week's supply of SQ-LNS is lower, all else equal, among households that previously participated in the iLiNS-Zinc clinical trial. All participants in the clinical trial received SQ-LNS for free (either as part of the clinical trial or after the clinical trial as part of a control group), so these households had extended, first-hand experience with LNS prior to the auction. The negative association with WTP for SQ-LNS relative to participants who were not part of the clinical trial may be a reflection of these households' knowledge of the short-term private costs and benefits of SQ-LNS. That is, household who participated in the clinical trial may perceive the costs to be higher and/or the benefits to be lower than households who have not had any direct experience with this particular product. Because SQ-LNS is provided for free to households who participated in the clinical trial, the negative relationship may also reflect a price anchoring effect whereby WTP is "anchored" to the previous price of zero.

Other statistically significant determinants of WTP for a week's supply are participant gender, weekly income, television ownership, and the asset index. WTP for SQ-LNS is higher, ceteris paribus, among male auction participants in the fixed effects specification, while the relationship between the household asset index and WTP is negative in this specification. Household ownership of a television is positively associated with WTP in the specifications with and without fixed effects. Participant income is negatively associated with WTP without fixed effects, but the magnitude of the effect is quite small.

Like WTP for a week's supply elicited from the auction, long-term hypothetical WTP for SQ-LNS is lower, all else constant, among households who participated in the clinical trial and higher among male participants. Household food insecurity is negatively associated with long-term WTP, where more food *in*secure households have a lower willingness to pay, all else equal. In specification three without fixed effects, the association between the age of the participant's youngest child and WTP is positive and significant.

4.2 Estimation of Price Elasticity of Demand for SQ-LNS in Market Trial

In this sub-section, we exploit two parts of the market trial to estimate the price elasticity of demand for SQ-LNS: the stage one MPCR-based low-high price treatment and the price drop after week 17 that marked the transition to stage two of the trial. In the first case, we estimate (arc) elasticities directly using total sales by village. Since the low price (150 CFA/strip) is 50% lower than the high price (300 CFA/strip), we can directly compute an arc elasticity of demand for SQ-LNS based on the percent change in demand in low price villages relative to high price villages. We normalize total SQ-LNS demand by the size of the target population, which we estimate as the number of children under age 2 in each village. Specifically, if we denote the total number of sachets sold in low and high price villages, respectively, as $Q_L = \sum_h q_{Lh}$ and $Q_H = \sum_h q_{Hh}$, where *h* indexes households, and their respective target populations as N_L and N_H, then a raw arc elasticity of demand is given by:

$$\eta_{Raw} = \left| \frac{(Q_L/N_L - Q_H/N_H)/(Q_H/N_H)}{-50\%} \right| = 2\left(Q_L/N_L - Q_H/N_H\right)/\left(Q_H/N_H\right) \qquad (1)$$

Note that since we normalize by target population size, this elasticity indicates the price sensitivity of demand for SQ-LNS in terms of sachets per target child.

In order to reflect the MPCR structure of the market trial, we devise a pairwise-corrected arc elasticity of demand based on the MPCR population estimator proposed by Imai et al. (Imai et al., 2009). This pairwise-corrected elasticity, essentially a weighted average of the pairwise arc elasticities of demand, is as follows

$$\eta = \sum_{k=1}^{7} \frac{\left(N_{Lk} + N_{Hk}\right)}{N} \frac{2\left(Q_{Lk}/N_{Lk} - Q_{Hk}/N_{Hk}\right)}{Q_{Hk}/N_{Hk}} \qquad (2)$$

where subscript *k* denotes the matched village pairs and subscripts *L* and *H* indicate the random assignment of the villages in each pair to low and high price, respectively.

Note that although villages were assigned to treatment, in some cases households traveled to neighboring villages to take advantage of lower prices. Our vouchers enable us to pinpoint such 'displaced' sales and suggest that they are relatively rare, occur predominantly between two specific high price villages and two low price villages, and were virtually non-existent until the second month of the trial. As a correction for these displaced sales, which would artificially inflate our arc elasticity measures, we attribute sales by home village of the buyer. This as a conservative correction for displaced sales because it implicitly assumes that households would have purchased SQ-LNS at the high price in their home village if it had not been available in another village at the low price.[7] We prefer to be conservative in this case because our coupons do not enable us to test for missing purchases from households that simply choose not to purchase SQ-LNS once they learn of a lower price in another village. While we are confident based on reports from our market agents that such missing purchases are rare, we prefer to be conservative at this stage.

Since these arc elasticity measures are not estimates with standard errors, we use bootstrapped samples to generate standard errors. In creating these bootstrapped samples, we assume each purchase transaction is independent. We choose not to cluster these bootstrap samples by household because doing so effectively over-weights repeat purchases relative to initial purchases. These arc elasticity measures and their 95% confidence intervals are shown graphically in Figure 8.

Our preferred estimates are the three 'pairwise-corrected' arc elasticities shown in this figure. Based on these estimates, demand for SQ-LNS appears to be very price sensitive. This is particularly true for repeated purchases, where price elasticity of demand is more than three times more elastic than first-time purchases – a difference that is both statistically significant and meaningful in magnitude. This result is especially important given that the intended benefits associated with SQ-LNS apparently hinge on children consuming it daily.

As an alternative perspective on the price sensitivity of household demand persistence, we estimate the following random effects model

$$D_{ijt} = \alpha_0 + \boldsymbol{\alpha}(lowprice_j \#\# i.week_t) + \delta_i + \phi_j + (\upsilon_i + \varepsilon) \tag{3}$$

where D_{ijt} indicates demand for SQ-LNS measured as three week moving average number of sachets purchased per day for household *i* in village *j* and week *t*, δ_i is a voucher source fixed effect, ϕ_j is a village pair fixed effect to correct for the MPCR design of the randomized low and high prices, and υ_i is a voucher (household) random effect. To be conservative, we cluster the standard errors in this specification by village rather than by vendor. The full interactions of the low price treatment by village and weekly dummy variables allows for the most flexible estimation of the evolution of the sensitivity of

[7] As another correction for displaced sales, we can restrict the analysis to the first four weeks of the trial. This yields estimates that are comparable, but less precise because of the smaller sample.

demand persistence to price. To compute D_{ijt} in this model, we take observed purchases as tracked by voucher booklets and assume non-purchases for weeks in which a given household made no SQ-LNS purchases.[8]

We depict the results of this estimation graphically in Figure 9. The conditional average demand for SQ-LNS is statistically higher in low price villages and initially fades less quickly, but the overall pattern of demand erosion over time is quite similar between high and low price villages. After two months, demand drops to about 0.3 sachets/day on average even for households in low price villages. This low level of supplementation is likely to yield few physical growth and cognitive development benefits.

To further characterize demand for SQ-LNS, we can analyze the change in demand induced by the price drop after week 17. Figure 10 graphically depicts regression results of weekly fixed effects on average sachets purchased per week. In the first 17 weeks of the trial, the distinction between high and low price villages is clear and statistically significant. The effect of the price decrease is also clear. Interestingly, this effect is (statistically) entirely due to new buyers being drawn into the market. That is, existing buyers respond very little to the price drop, but the drop does entice a new cohort of buyers into the market. This price change was not accompanied by any promotional activities to advertise the new lower price for SQ-LNS, suggesting that these new buyers learned by word-of-mouth or directly from the vendors that the price had been reduced 50%.

4.3 Analysis of SQ-LNS Loyalty Card Effects

Next, we analyze the effect of the non-price promotion introduced in phase three of the trial. While the overall effect of the promotional activities on SQ-LNS demand is evident in Figure 4 – roughly a 50% increase in demand that fades away in five or six weeks – we are particularly interested in the effect the loyalty card has on purchases. As a secondary objective, we are also interested in testing whether intra-household dynamics shape this effect. Regression analysis of our experimental auction data suggested men have a substantially higher long-term WTP for SQ-LNS than women. Further, during the first phase of the trial, several of our vendors shared similar perceptions about what is different about households that regularly purchases SQ-LNS. The most common perceived similarity involved the engagement and commitment of the father of the target child[9] as a necessary condition for persistent demand: Only households in which the father was committed to the care of his children and saw SQ-LNS as a potentially valuable product regularly purchased the product. The design of the promotional activities

[8] For households that received their voucher booklet in the auction or from the iLiNS project as participating households, we assume all non-purchases are zero purchases. For households that received voucher booklets directly from vendors or from iLiNS friends we only assume non-purchases are zero purchases after the initial purchase. On the backend, we make no corrections for households whose target age children “age out” of the SQ-LNS window of 6-24 months because we have no way of knowing (yet) when this occurs. This implies that some of the erosion of demand that we observe may be due to households “aging out” of this window, but this necessarily accounts for only a small portion of the demand erosion, which occurs in a matter of weeks rather than months.

[9] We use the term ‘father’ for simplicity. While most of the male caretakers in our sample – indeed in the region – are fathers, there are some uncles, brothers and grandfathers acting as caretakers as well.

enables us to test whether the participation of the father in the promotional sessions affects subsequent demand persistence. We can also test whether loyalty cards won by fathers have a different effect than those won by mothers.

We test these hypotheses using the following specification:

$$D_{ijt} = \lambda_0 + \boldsymbol{\beta}(card_i \,\#\#\, i.postpromo\_period) + \lambda_1 shirt_i + \lambda_2 male\_card_i + \lambda_3 male\_shirt_i \\ + \lambda_4 two\_participants_i + \lambda_5 male\_participant + \gamma_t + \theta_j + (\upsilon_i + \varepsilon) \qquad (4)$$

where D_{ijt} indicates demand for SQ-LNS measured as three week moving average number of sachets purchased per day for household *i* in village *j* and week *t*, *card* is a dummy variable that indicates whether the household won a loyalty card during the promotional session, *postpromo_period* is a categorical variable indicating four week periods after the promotion, *shirt* indicates whether someone in the household won the second prize shirt, *male_card* (*_shirt*) indicates whether a male member of the household won a loyalty card (shirt), *two_participants* indicates whether the household had more than one participant at the session, *male_participant* indicates whether a male member of the household participated, γ_t is a week fixed effect, θ_j is a village fixed effect, and υ_i is a voucher (household) random effect. Again, we cluster standard errors in this specification by village.

Table 4 displays the results of this regression for all households that participated in the promotion as well as two subsamples depending on whether these participating households had purchased SQ-LNS prior to the promotional sessions or not. The effect of the loyalty card on demand persistence is large relative to baseline demand and statistically significant. Specifically, possession of a loyalty card more than doubles a household's demand for SQ-LNS. Statistically, this effect persists for several (four week) periods after the promotion. Although the point estimates for interactions with subsequent 'post-promotion' periods are all negative, suggesting that the effect of the loyalty card fades over time, these are mostly insignificant. The only exception is one interaction term for new buyers. Although we hesitate to make too much of this difference in statistical precision, this pattern is consistent with a selection story in which existing buyers – who demonstrated greater interest in SQ-LNS even before the promotional sessions – are more responsive to the loyalty card over time than new buyers – who had not selected into the SQ-LNS market prior to the promotional campaign. There is little evidence that who wins the card (or shirt, for that matter) shapes subsequent demand. While this does not necessarily contradict the anecdotal evidence that the engagement of men is critical to demand persistence, it does suggest that a man who wins a reward card does not subsequently induce more frequent SQ-LNS purchases.

Figure 11 displays the conditional demand for SQ-LNS for different four-week post-promotion periods. The effect of the loyalty card is clear in this figure, although the level of demand even with a loyalty card is still quite low relative to the full compliance rate of 1.0 (assuming one target age child per voucher and no sharing with other household members). Figure 12 displays Figure 9 and the left panel of Figure 11 side-by-side to facilitate comparison of the price and non-price impacts on demand. Specifically, whereas low price villages faced a 50% price reduction, loyalty cardholders enjoyed an effective 35-40% reduction price reduction based on the value of the loyalty rewards offered to cardholders. Although the randomization does not allow for a rigorous comparison of the respective demand effects of these two reductions, the pattern in Figure 12 suggests that the effects are roughly comparable in magnitude. Based on the point estimates and some assumptions that extend the low-high price demand differential into phase three, there appears to be a non-price component to the demand effect of the loyalty card above-and-beyond the value of the in-kind reward it offers, but we lack the statistical power for any strong inferences in this regard.

4.4 Analysis of Seasonality of SQ-LNS Demand Persistence

Children who are likely to benefit the most from micronutrient supplementation live in vulnerable households that struggle to provide for the full nutritional and health needs their members. As in many such contexts, the households in our study area are particularly vulnerable to seasonal fluctuations due largely to seasonal rainfall because agriculture is almost entirely rainfed in this region. This raises a particularly important dimension to household demand persistence for SQ-LNS. How much do seasonal rainfall fluctuations shape demand for SQ-LNS in this context?

This question raises several potentially important considerations. Liquidity constraints, which fluctuate predictably according to the agricultural calendar and unpredictably according to production or market shocks, may hamper demand in lean seasons and may increase demand when good rainfall improves a household's expected harvest. The production calendar also demands investment of time, attention and both purchased and non-purchased inputs. These seasonal investments may directly compete with SQ-LNS for scare household resources. To the extent that key production times are associated with the timing of rainfall, rainfall may drive much of this competition for resources. Finally, households may consider SQ-LNS to be particularly valuable during the lean season when diet diversity is low or even in anticipation of a harder-than-usual lean season. Providing explicit tests of these different potential pathways that link local rainfall to SQ-LNS demand persistence is beyond our data, but we can nonetheless provide some initial evidence of how rainfall fluctuations shape demand persistence.

To provide some initial evidence in this regard, we collect rainfall data for our villages from the ARC2 dataset developed by the National Oceanic and Atmospheric Administration (NOAA) for programs of the U.S. Agency for International Development (USAID)/Famine Early Warning Systems Network (FEWS-NET). The ARC2 dataset is derived from four sources: infrared satellite data to estimate cloud-top temperatures, ground-based rain gauge observations, and microwave SSM/I and AMSU-B satellite data. ARC2 offers the advantage of a very high spatial (0.1 deg x 0.1 deg) and temporal (daily) resolution, and is updated on a continuous basis. Validation of ARC2 with independent gauge data showed bias in certain regions and seasons, but an error rate that is comparable to other techniques (Novella and Thiaw, 2013). We use these rainfall data to construct z-scores of weekly cumulative rainfall by village compared to long-run average rainfall for that week and village.

$$D_{ijt} = \lambda_0 + \boldsymbol{\beta}_1(z\_rain_{jt} \#\# i.ag\_period_t) + \boldsymbol{\beta}_2(z\_rain_{jt} \#\# T_{ij})$$
$$+\lambda_1 week_t + \lambda_1 week_t^2 + \theta_j + (\upsilon_i + \varepsilon)$$

Table 5 reports the results of a four demand regressions, two each for phase one (late production season until harvest) and phase three (planting through late production season). This specification includes cumulative rainfall as both a stand-alone variable and interacted with low price village and loyalty card for phase one and three, respectively, as well as with different production periods within each of these phases. We find a strong, positive effect of cumulative rainfall on SQ-LNS demand during the late production season of phase one. This effect is strongest for high price villages. Higher than average rainfall in the late harvest period (for crops other than maize) strongly reduces SQ-LNS demand, potentially because such late-season rainfall complicates harvest and post-harvest activities and threatens effective yield. In phase three, we find much weaker evidence of rainfall effects on demand. This may reflect the fact that rainfall has very different implications in early versus late production periods, but may also be shaped by the fact that the design of the trial was cumulative and might have attracted different kinds of households to the SQ-LNS market at different phases. With continued analysis, we hope to shed more light on these effects and possible mechanisms that transmit them.

4.5 Analysis of Household Characteristics and SQ-LNS Demand Using Endline Sub-sample

At the conclusion of the market trial, we administered a household survey among a random sample of households from the trial area. To construct this sub-sample, we stratified households based on their SQ-LNS purchase patterns, including one strata of households with target age children who had never purchased the product before.

One of the objectives of this endline survey is to characterize different types of households according to their purchase patterns. We construct two summary measures of SQ-LNS purchase intensity for each household in this sample. First, we average the number of sachets purchased per week. Second, we build on the measures of demand persistence used above by computing the number of weeks that a each household had a three week moving average purchased SQ-LNS per day above a threshold of 0.4 sachets/day.

Table 6 reports preliminary results of a regression of these two summary measures of demand persistence for the households in our endline sub-sample as a function of several observable characteristics. These results suggest that household assets – a proxy for wealth – are strongly related to SQ-LNS demand: richer households demand more SQ-LNS. We also find that households that purchase more than half of the food they consume have higher demand persistence. As a test of whether father involvement influences demand persistence, which is what many vendors reported, we construct a factor analytic index based on father involvement in SQ-LNS purchase and medical expense decisions.[10]

[10] This index is constructed based on response to SQ-LNS questions about who pays, purchases from the vendor, and decides how much to purchase and general medical questions about who pays and makes decisions about medical treatment of children in the household.

We find that this does indeed increase a household's demand persistence, although the estimate is shy of conventional levels of statistical significance.

5 Conclusion

The unprecedented success of Plumpy'Nut® as a treatment for severe acute malnutrition among young children has sparked efforts to develop similar Lipid-based Nutrient Supplement (LNS) products aimed at preventing rather than treating undernutrition. In response, three distinct LNS product classes have emerged, including 'small-quantity' LNS products (SQ-LNS) designed exclusively to prevent undernutrition. This move along the LNS continuum to preventative formulations has some fundamental practical implications for supply chains. Whereas major public and private players have structured large- and medium-quantity LNS supply chains, they are unlikely to take the lead with SQ-LNS products – which implies that the private sector will likely play a greater role in the distribution of these products through markets. We use experimental markets in rural Burkina Faso to shed light on household demand for SQ-LNS and explore associated distribution challenges.

We find that price elasticity of demand for SQ-LNS is high on average, but that elasticity for repeat purchases is significantly higher than for first-time purchases. This has important implications for delivery design for SQ-LNS – and possibly for other nutrition investments that require daily (or at least regular) consumption: Many households may be willing to pay close to market prices to try SQ-LNS products for a week or two, but sustained demand week-after-week and month-after-month is extremely sensitive to price. In the third phase of the market trial, our promotional activities revived demand, but it subsequently and steadily falls off. Under a sustained promotional campaign, demand may be propped up for several weeks or months, but our research design does not allow us to test such a sustained campaign. We do find strong evidence that a simple loyalty card dramatically expands demand persistence. Which household member acquires the loyalty card does not affect demand, suggesting a degree of intra-household efficiency with regards to SQ-LNS purchase decisions.

Taken together, these results imply that innovative public-private delivery models that reduce out-of-pocket costs may have pronounced effects on compliance with the required daily supplementation regimen. Even where SQ-LNS products are cost-effective as a nutritional investment, private demand may cover less than half the production and distribution costs of SQ-LNS, underscoring the need for hybrid private-public delivery strategies.

By jointly analyzing two separate demand angles – namely, experimental auction-based demand curves and actual demand from local vendors – we make a broader methodological contribution to the growing set of experimental economic evaluations of health interventions. In ongoing analyses, we are able to explore the external validity of consumer valuation elicited via an experimental auction. By contrasting and comparing the results from these demand assessment phases we provide methodological insights for future research on consumer valuation and demand. The experimental auction results correspond roughly to the market trial results for first-time purchases, but bear little resemblance to sustained demand for SQ-LNS evident in subsequent purchases. This high price elasticity of persistent demand is difficult to detect with either hypothetical or auction-based demand elicitation.

In sum, the evidence presented in this paper emphasizes the need for creative public-private arrangements to deliver SQ-LNS products to households with children threatened by undernutrition. Even if rigorous evidence suggests that these products are cost-effective, they will end up underutilized and will fail to reach their full potential if they are left to either the public or the private sector alone to distribute. The public sector clearly has a role to play in providing the investments, infrastructure and legal frameworks required to enable the private sector to engage in these LNS markets. While direct subsidization – a prototypical feature of public-private models – may play an important role, the public sector can also help reduce production costs by reducing trade barriers and tariffs for key production inputs. Private firms in the food and beverage sector and other low margin-high volume consumer goods have proven to be remarkably nimble and innovative in rural Africa. Focusing some of this supply chain expertise to bear on SQ-LNS markets could bring crucial innovations in production processes and in distribution and marketing. But fully tapping this expertise will require the current public and private stakeholders in childhood nutrition to embrace this as an opportunity, to build partnerships based on trust, and to ensure that associated regulatory systems function effectively and efficiently.

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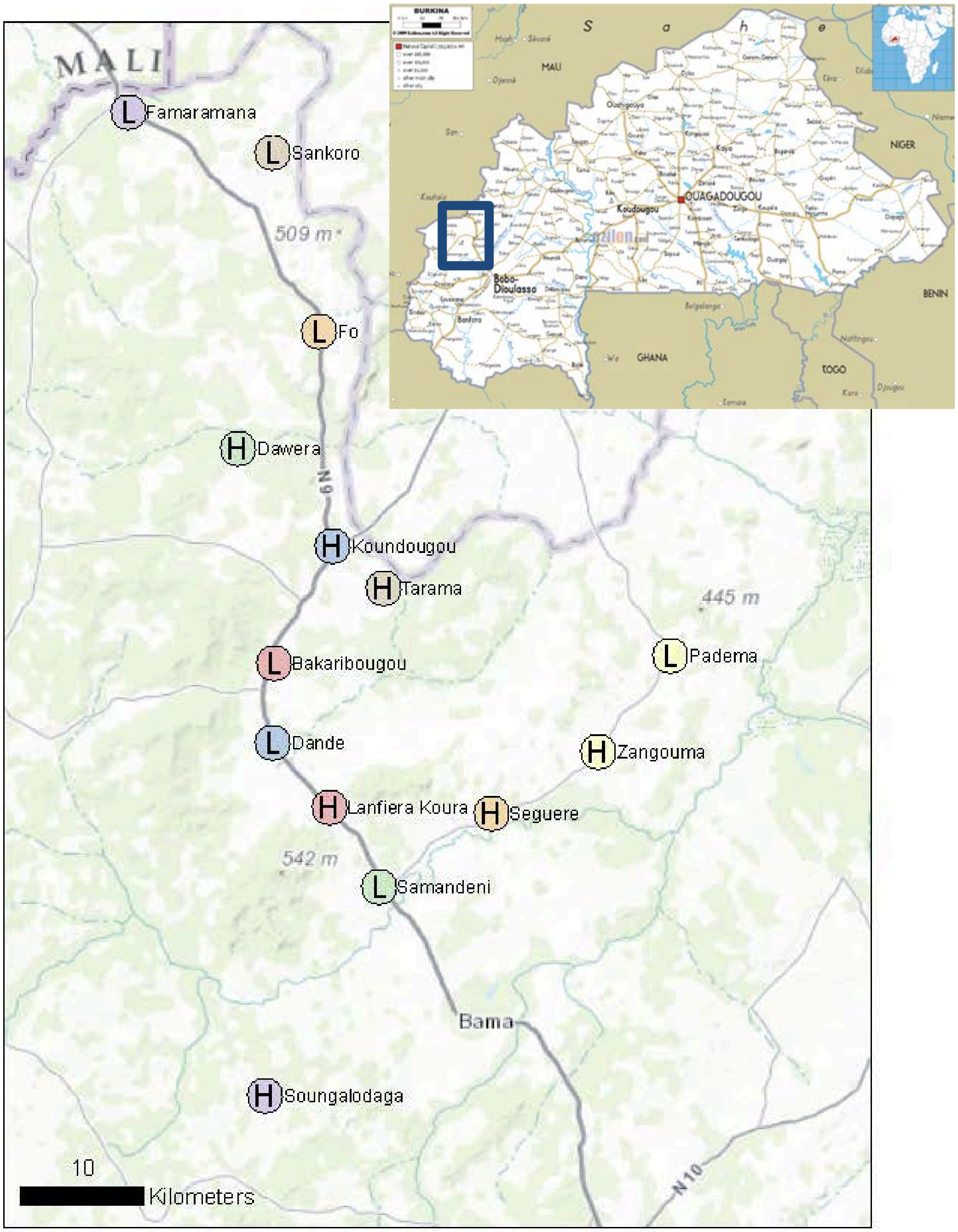

Figure 1 Map of villages in northwest Burkina Faso (north of Bobo-Dioulasso) included in SQ-LNS auction and market trial. Color of village dots indicates village pairs and letters denote random high (H) and low (L) price assignment within pairs used during phase one of the market trial. At the conclusion of phase one (after week 17), SQ-LNS was priced in all markets at the low price.

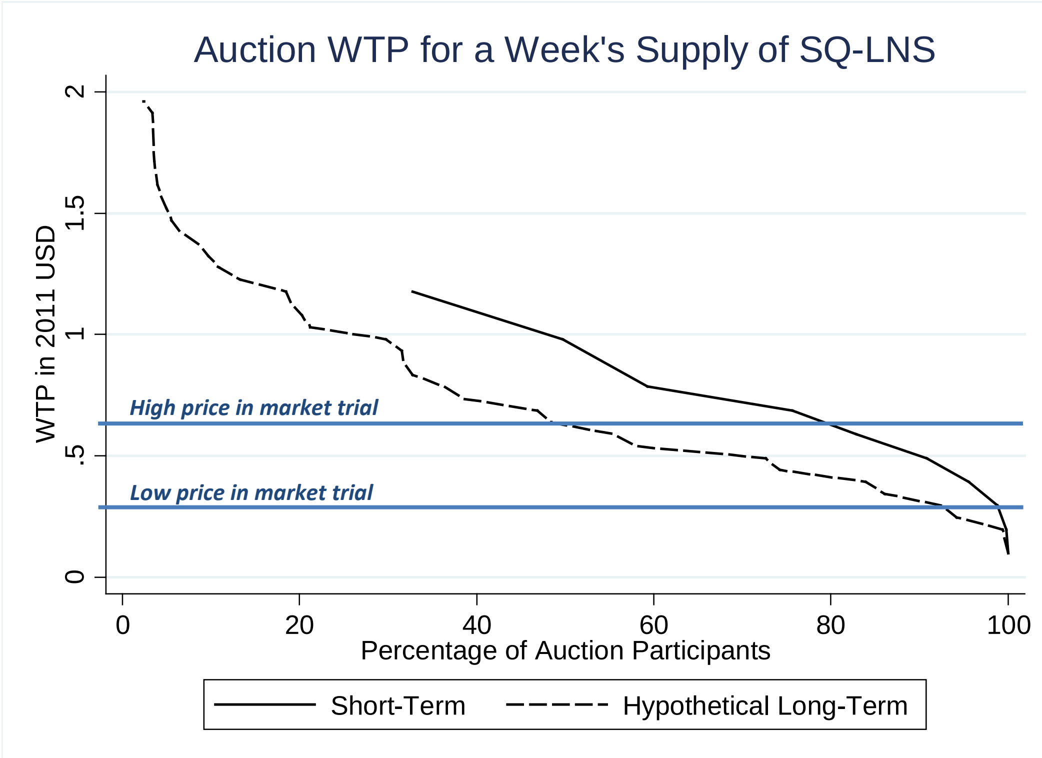

Figure 2 Demand curves for SQ-LNS based on experimental auction for a week's supply and follow-up hypothetical long-term demand questions.

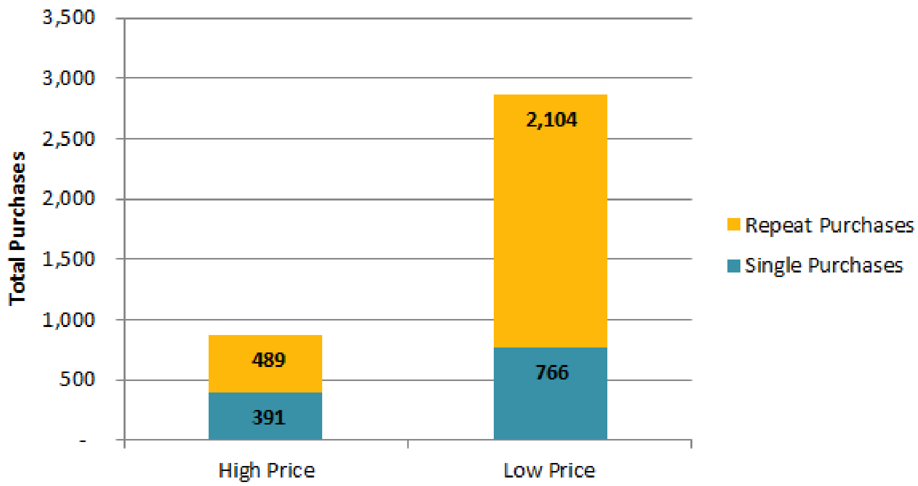

Figure 3 Total number of sachets purchased in phase one of market trial (weeks 1-17) by low and high price villages differentiated by single (first) and repeat purchases.

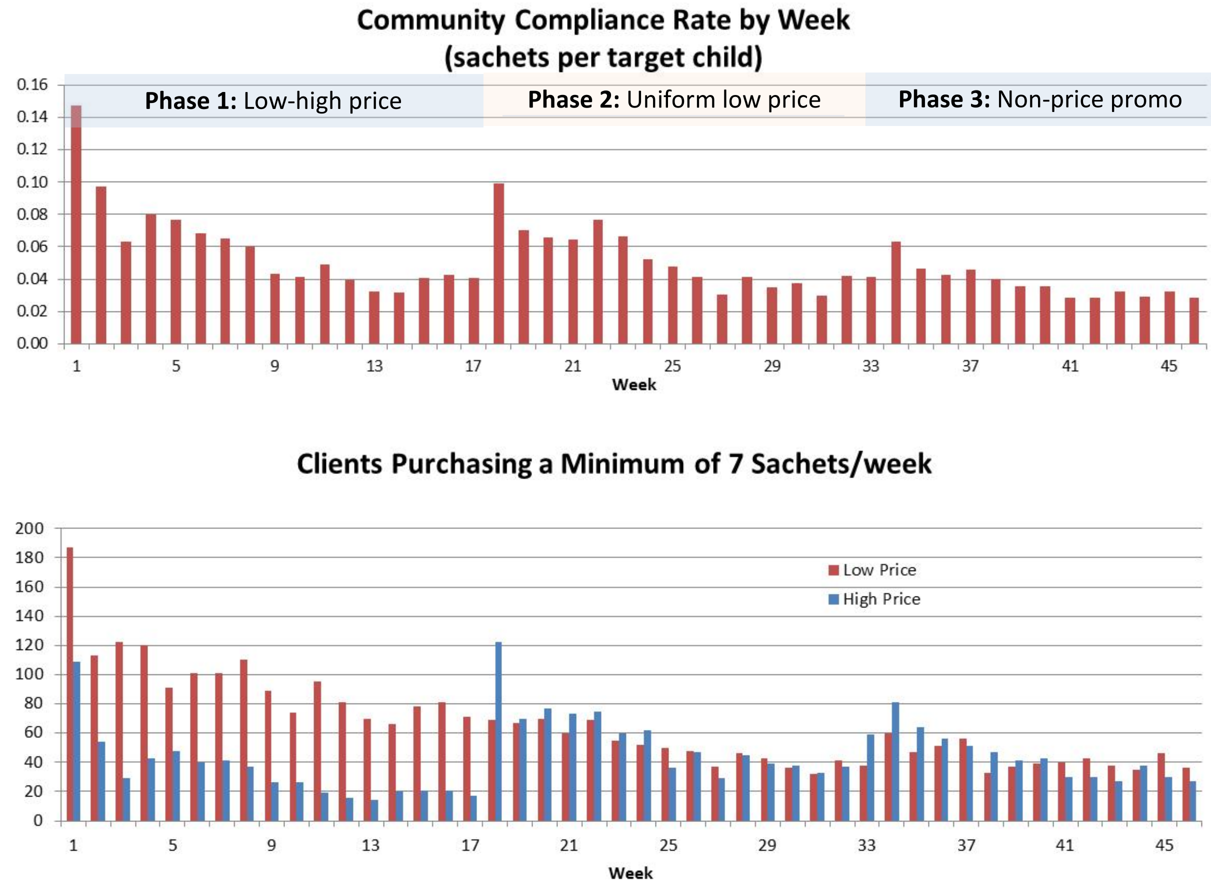

Figure 4 The evolution of the 'community compliance' rate (top panel) computed as the total number of sachets sold divided by the total number of target age children in our 14 villages and of the number of households purchasing a minimum of one strip (seven sachets) per week (bottom panel).

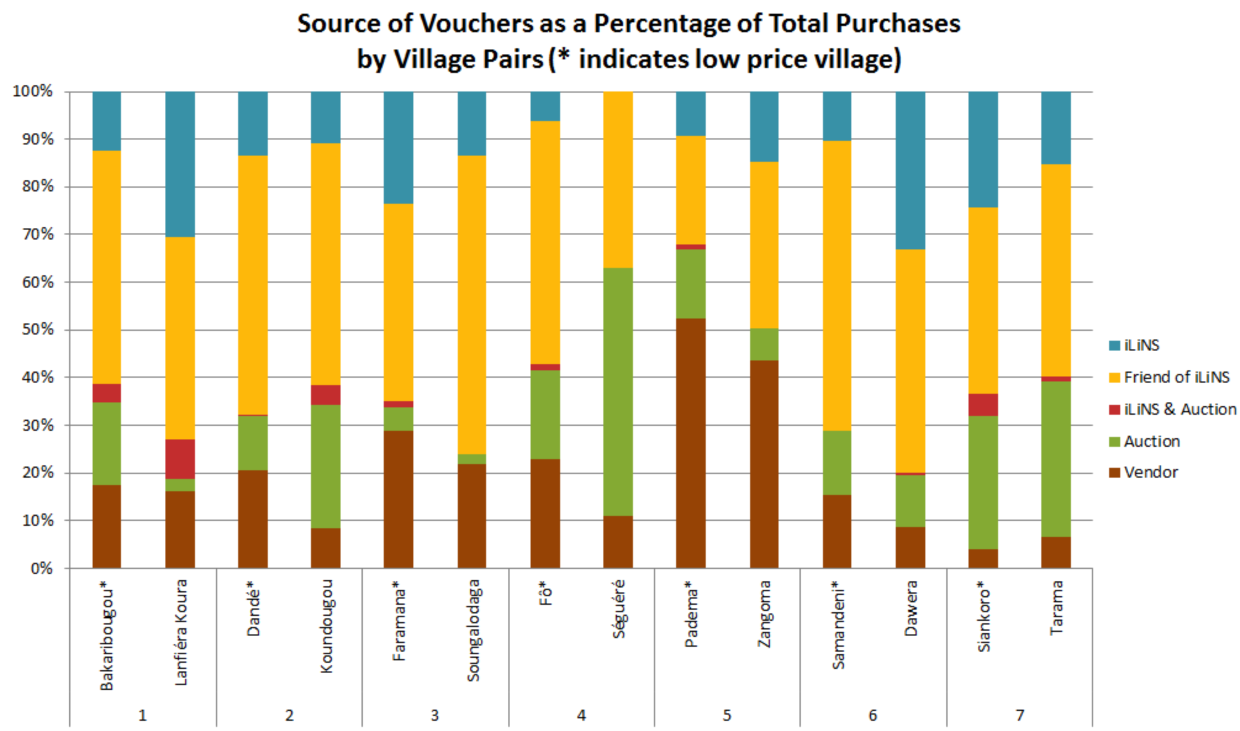

Figure 5 Distribution of total purchases over voucher source by village pair

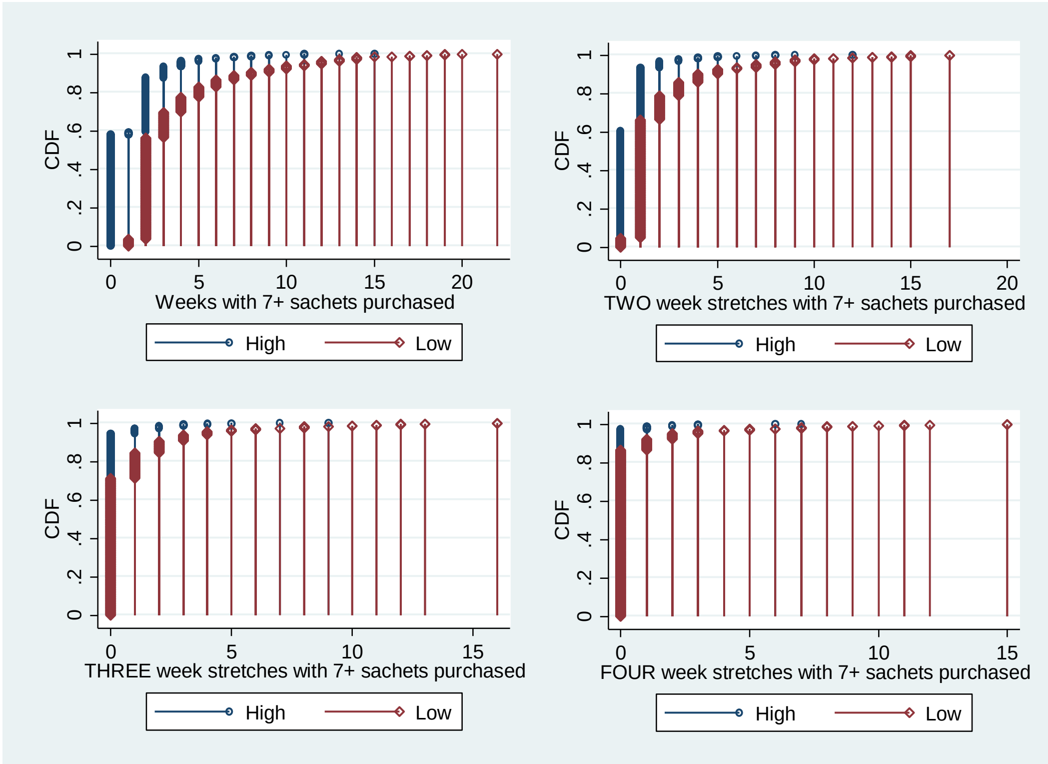

Figure 6 Cumulative distribution functions of consistent daily purchases by low price and high price treatment during phase one of market trial (weeks 1-17).

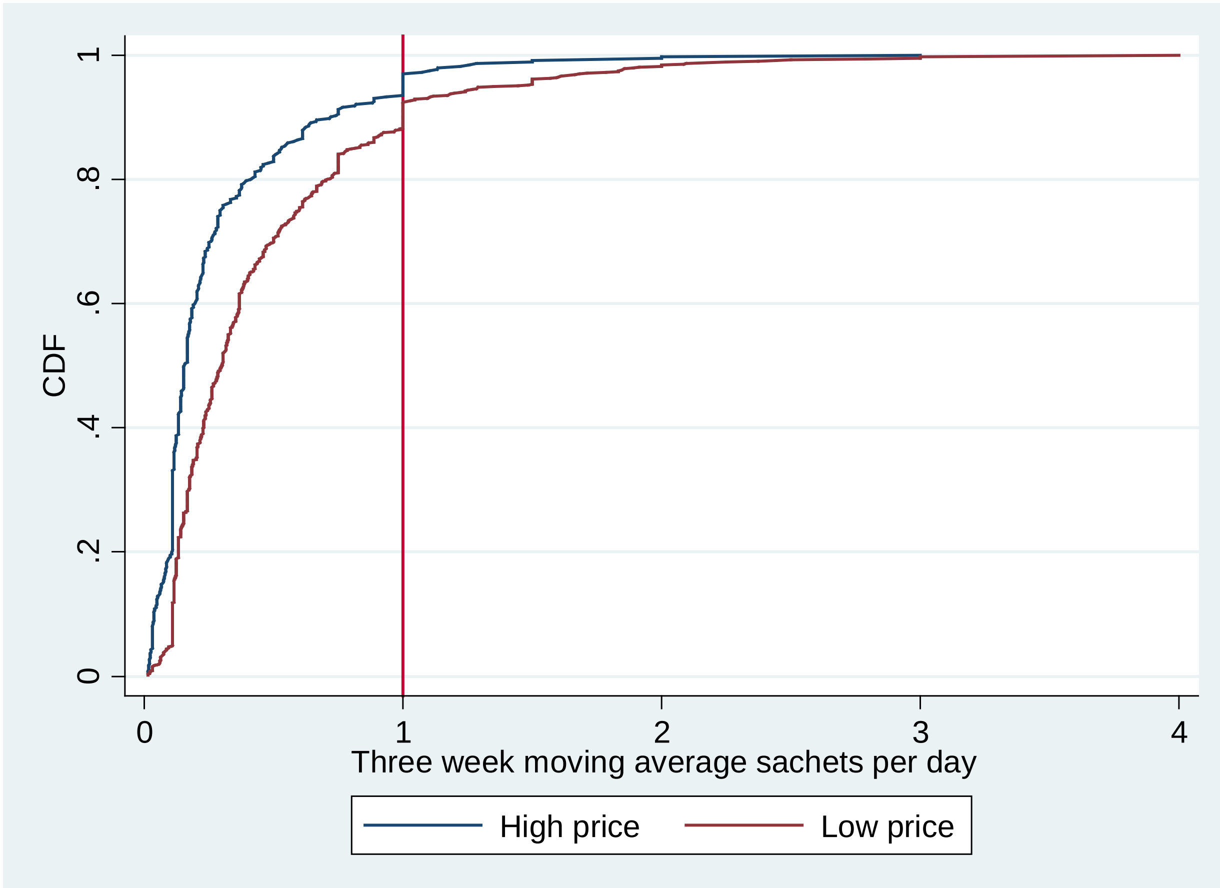

Figure 7 Cumulative distribution functions for average sachets purchased per day (three week moving average) by low price and high price treatment during phase one of market trial (weeks 1-17).

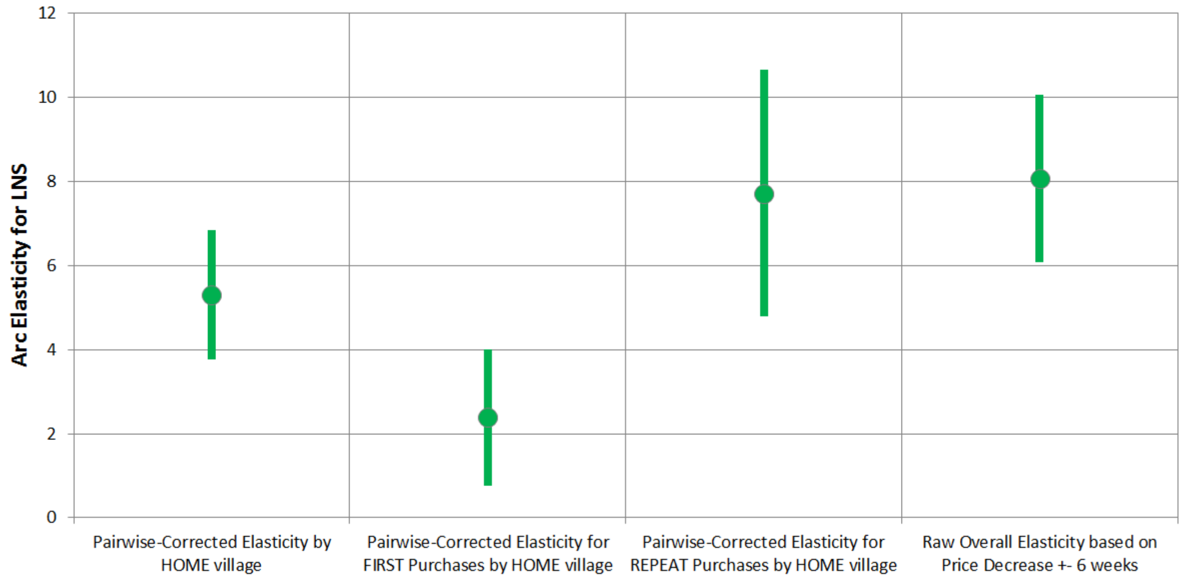

Figure 8 Directly computed arc price elasticity of SQ-LNS demand with bootstrapped 95% confidence intervals.

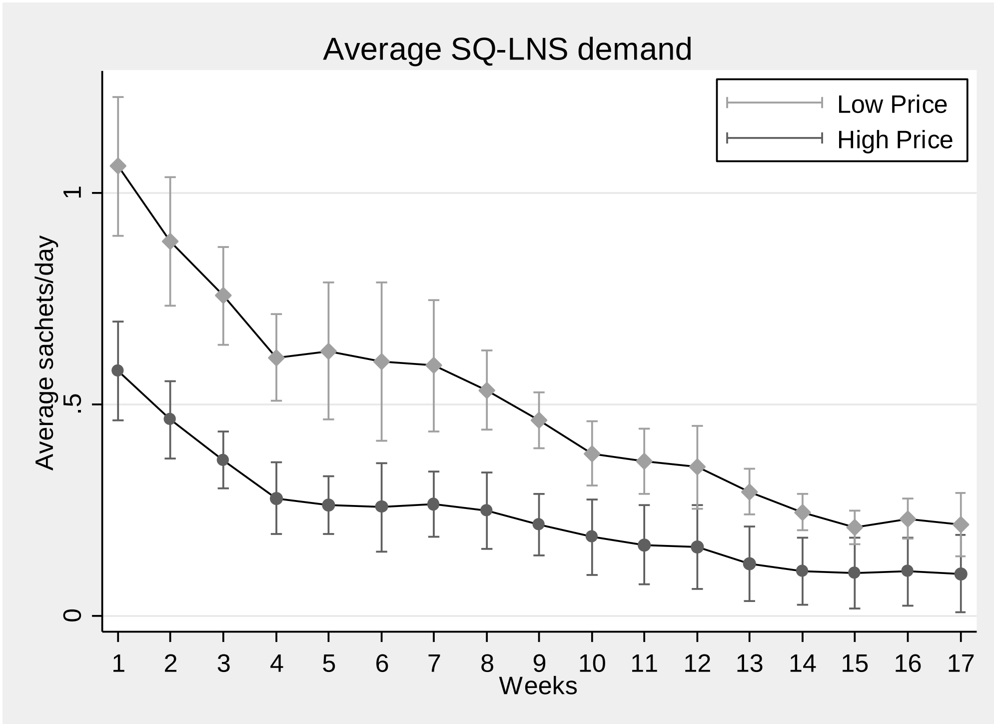

Figure 9 Conditional average demand measured as three-week moving average sachets per day per household during phase one of the trial in high and low price villages (bars depict 90% confidence intervals), including controls for voucher source fixed effects and matched-pair fixed effects.

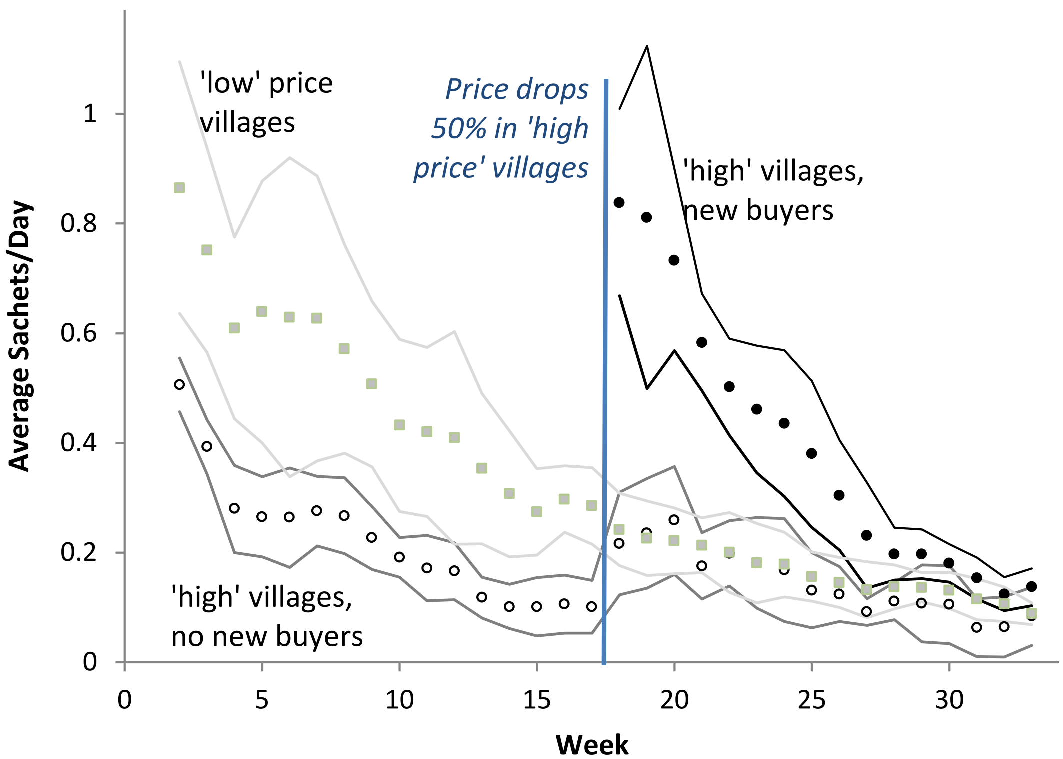

Figure 10 Unconditional average demand by week (three week moving average of weekly LNS purchases for each household) in 'low' and (initially) 'high' price villages (after the price drop, SQ-LNS was priced the same in all villages). Lines indicate 90% confidence intervals around these weekly averages based on standard errors clustered by village.

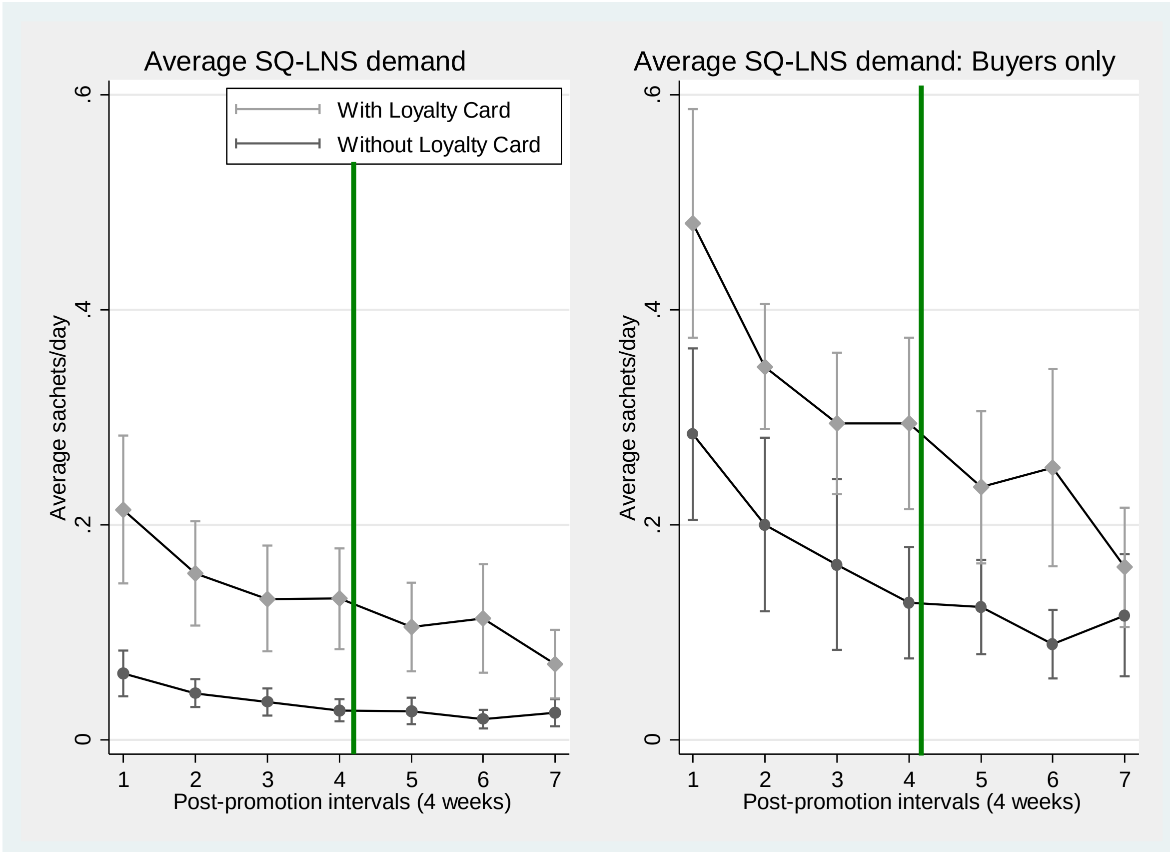

Figure 11 Conditional three week moving average of sachets purchased per day after promotional activities for households that won a loyalty card and those without a loyalty card, including all households that participated in the promotion (left) and only those that purchased at least one sachet of SQ-LNS after the promotion (right). Error bars depict 90% confidence intervals based on robust standard errors clustered by village. Vertical line indicates the earliest point that loyalty card holders could reach the maximum number of rewards.

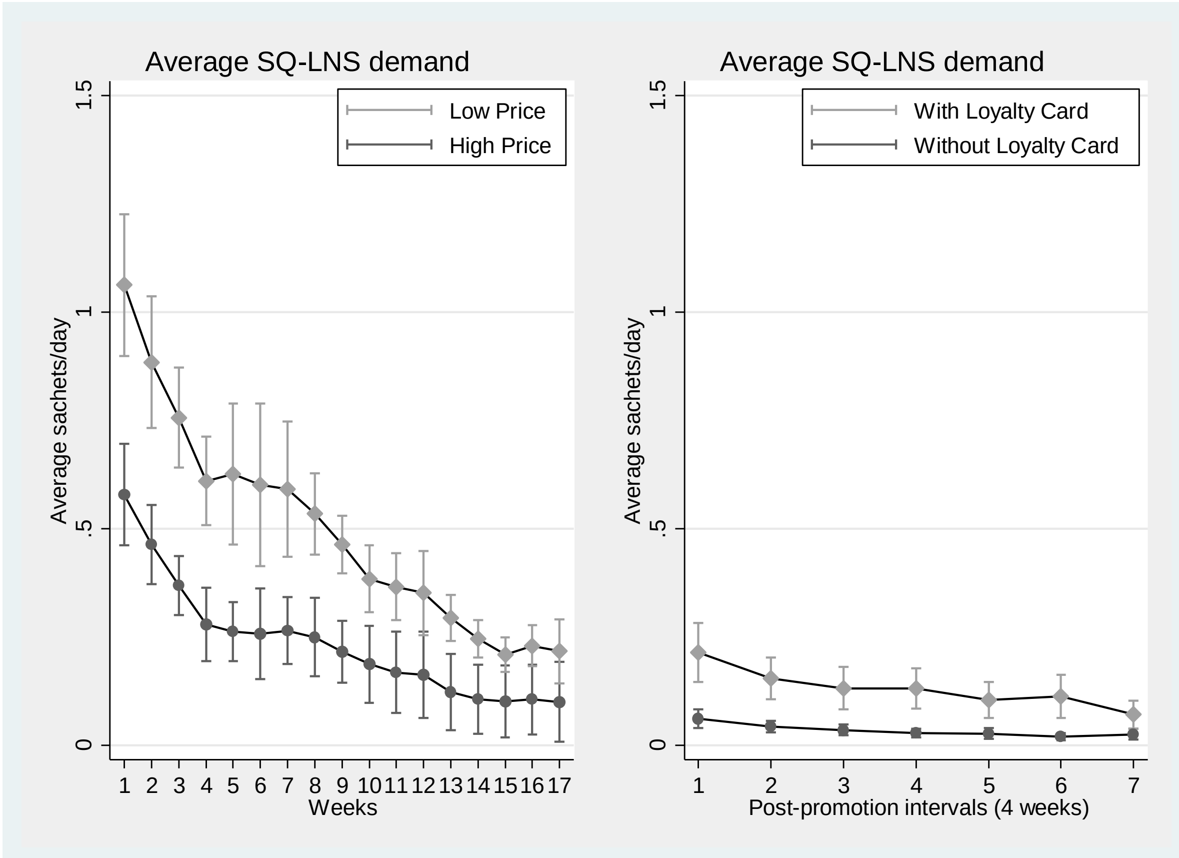

Figure 12 Comparison of average SQ-LNS demand during low price-high price phase one (left) and phase three with loyalty card (right). Low price represents a 50% reduction from high price. Based on the value of the small reward offered to loyalty card holders, this provides an effective in-kind price reduction of about 35-40% from the low price.

Table 1 Typology of differentiated LNS product classes

	Intended purpose	Typical daily ration	Supply chain features
Large-quantity LNS (Ready-To-Use Therapeutic Foods (RUTF))	Treat severe acute malnutrition (SAM).	180-280g (1000-1500 kcal) to provide 100% of energy demands for 9-12 month old child outside of breast milk.	Private sector production with public sector procurement (UNICEF, MSF, WFP) and public distribution in collaboration with national health programs. Distribution through markets often illegal.
Medium-quantity LNS (Ready-To-Use Supplementary Foods (RUSF))	Treat moderate acute malnutrition and prevent SAM.	45-90g (250-500 kcal) to provide 50-100% of energy demands.	Private sector production with predominantly public sector procurement (UNICEF, MSF, WFP) and public distribution in collaboration with national health programs. *Expected: Some private sector distribution through markets.*
Small-quantity LNS (SQ-LNS)	Prevent undernutrition; promote normal growth and development.	20g (110 kcal) to provide <50% of energy demands.	Private sector production. *Expected: Sparse public procurement and distribution and active private sector distribution through markets.*

Source: (Arimond et al., 2013).

Table 2 Descriptive statistics for households participating in the experimental auction (eWTP). Summary statistics for hypothetical WTP (hWTP) elicited from the broader iLiNS sample are provided for comparison.

	Variable	Definition	Mean/ Frequency	Std Dev/ Percent	Min, Max
Auction Participants	Male	=1 if participant is male	259	52.3%	
	Education	Years of education	1.9	1.9	0, 5
	Weekly Income	Self-reported income in past seven days (4th quarter 2011 USD)	22.89	72.1	0, 784.6
	Height	Height in meters	1.68	0.1	1.4, 1.9
	BMI	Body mass index (weight/height^2)	21.8	2.7	16.2, 34.3
Auction Households	Household Size	Number of household members	8.0	3.9	2, 27
	Child Age	Age of participant's youngest child in months	13.1	5.1	5, 24
	PC Weekly Food Expenditures	Per capita household expenditures on food in the past seven days (4th quarter 2011 USD)	1.22	2.6	0, 42
	TV	= 1 if household owns a television	91	18.4%	
	Asset Index	Proxy measure of household's socioeconomic status based on asset ownership	0.0	1.0	-4.5, 1.3
	Food Insecurity Score	Indicator of food insecurity in the household	1.8	2.4	0, 11
	Clinical Trial Household	= 1 if household participated in the iLiNS-Zinc clinical trial	103	20.8%	
eWTP	Auction WTP	WTP for week's supply of LNS (4th quarter 2011 USD)	0.85	0.29	0.10, 1.18
	Auction hypothetical long-term WTP	Long-term WTP for week's supply of LNS (4th quarter 2011 USD)	0.75	0.51	0.10, 4.86

Table 3 Tobit regression results of eWTP elicited in experimental SQ-LNS auction

	Variable	WTP for a Week's Supply (1) No Fixed Effects	WTP for a Week's Supply (2) Fixed Effects	Long-Term Hypothetical WTP (3) No Fixed Effects	Long-Term Hypothetical WTP (4) Fixed Effects
Participant Characteristics	Male (0/1)	0.0733	0.1042	0.1913***	0.2418***
		(0.0494) ‡	(0.0651)	(0.0611)	(0.0846)
	Education (yrs)	0.0088	0.0024	-0.0022	-0.0046
		(0.0110)	(0.0113)	(0.0148)	(0.0159)
	Weekly Income (2011 USD)	-0.0003*	-0.0002	-0.0001	-0.0000
		(0.0002)	(0.0002)	(0.0002)	(0.0002)
	Height (meters)	-0.2856	-0.1662	0.0196	0.1606
		(0.3306)	(0.3261)	(0.2962)	(0.2717)
	BMI	0.0024	0.0017	0.0097	0.0063
		(0.0077)	(0.0077)	(0.0085)	(0.0091)
Household Characteristics	Household Size	-0.0031	-0.0064	-0.0069	-0.0104
		(0.0049)	(0.0054)	(0.0050)	(0.0062)
	Child Age (mo)	0.0026	0.0006	0.0079**	0.0061
		(0.0033)	(0.0031)	(0.0033)	(0.0042)
	PC Weekly Food Expenditures	-0.0035	-0.0023	-0.0034	-0.0029
	(2011 USD)	(0.0061)	(0.0056)	(0.0069)	(0.0064)
	TV (0/1)	0.0963**	0.1073**	0.0692	0.1074
		(0.0444)	(0.0492)	(0.0719)	(0.0752)
	Asset Index	-0.0488*	-0.0663**	-0.0016	-0.0219
		(0.0258)	(0.0282)	(0.0327)	(0.0355)
	Food Insecurity Score	-0.0114	-0.0147	-0.0290**	-0.0307**
		(0.0100)	(0.0104)	(0.0118)	(0.0127)
	Clinical Trial Household (0/1)	-0.1023**	-0.0968**	-0.1711**	-0.1722**
		(0.0422)	(0.0443)	(0.0634)	(0.0695)
	Constant	1.2520**	1.0310*	0.3491	-0.8355*
		(0.5309)	(0.5531)	(0.4104)	(0.4208)
	Sigma	0.3915***	0.3753***		
		0.3915***	0.3753***		
	N	495	495	494	494
	Pseudo R^2/ R^2	0.028	0.085	0.084	0.155

Significance codes: *** (p < .01), ** (p < .05), * (p < .1)
Models specifications: (1) is tobit and does not include fixed effects; (2) is tobit and includes auction session fixed effects; (3) is OLS and does not include fixed effects; (4) is OLS and includes auction session fixed effects.
Note: Controls for market price in the practice rounds are included in all regressions (unreported).
‡Numbers in parentheses are robust standard errors, clustered at auction session level.

Table 4 Regression of three week moving average sachets per day purchases with buyer random effects for all households that participated in promotional sessions, for households that had purchased SQ-LNS before participating in the promotional sessions, and for 'new voucher' households that participated in these sessions but had not purchased SQ-LNS prior to the session.

	Three week moving average sachets/day		
	All HHs in promotion	Subsets of HHs in promotion	
		Existing buyers only	New buyers only
Loyalty card	0.16***	0.25***	0.11**
	(0.038)	(0.038)	(0.044)
… X Post-promo 2	-0.039	-0.071	-0.027
	(0.034)	(0.089)	(0.035)
… X Post-promo 3	-0.055	-0.062	-0.049
	(0.037)	(0.076)	(0.039)
… X Post-promo 4	-0.047	-0.041	-0.043
	(0.041)	(0.092)	(0.036)
… X Post-promo 5	-0.072*	-0.040	-0.078**
	(0.044)	(0.090)	(0.038)
… X Post-promo 6	-0.057	-0.059	-0.049
	(0.045)	(0.083)	(0.043)
… X Post-promo 7	-0.11**	-0.19**	-0.064
	(0.044)	(0.074)	(0.042)
Second prize	0.016	-0.021	0.030**
	(0.017)	(0.035)	(0.014)
Male won loyalty card	-0.0038	0.093	-0.018
	(0.036)	(0.087)	(0.024)
Male won second prize	-0.0086	0.068	-0.040**
	(0.026)	(0.073)	(0.016)
>2 participants from HH	0.047	0.031	-0.00021
	(0.049)	(0.080)	(0.024)
Male participant from HH	-0.014	-0.064*	0.014
	(0.018)	(0.034)	(0.011)
Constant	0.068*	0.16**	0.015
	(0.036)	(0.070)	(0.037)
Week FE	YES	YES	YES
Village FE	YES	YES	YES
Observations	0.068*	0.16**	0.015
Number of voucher	(0.036)	(0.070)	(0.037)

*** p<0.01, ** p<0.05, * p<0.1. Robust standard errors clustered by village in parentheses.

Unreported controls include post-promo period dummies and estimated week and village fixed effects.

Table 5 The effect of rainfall fluctuations (measured as z-scores relative to long-run cumulative rainfall by week) on weekly demand and demand persistence for SQ-LNS.

	Phase 1: July-Nov 2013		**Phase 3: Mar-Aug 2014**	
	Sachets purchased (weekly)	**Three week moving average sachets/day**	**Sachets purchased (weekly)**	**Three week moving average sachets/day**
Low price village	0.843	0.125		
	(0.514)	(0.0891)		
Loyalty card			0.747***	0.105***
			(0.167)	(0.0235)
Cumulative rainfall (z-score)	2.101***	0.225***	-0.0131	0.00160
	(0.608)	(0.0803)	(0.0524)	(0.00618)
…X Low price village	-2.877***	-0.545***		
	(0.761)	(0.141)		
…X Loyalty card			-0.226**	-0.0245
			(0.107)	(0.0156)
…X Maize harvest	-0.841	0.0130		
	(0.646)	(0.0686)		
…X Other harvest	-1.148	0.0737		
	(1.164)	(0.142)		
…X Planting			0.129	0.00944
			(0.0801)	(0.00754)
…X Growing			0.0425	0.00546
			(0.0729)	(0.0104)
…X Maize harvest			0.172	0.0170
			(0.127)	(0.0172)
Constant	3.146***	0.401***	3.211**	0.398**
	(0.648)	(0.0834)	(1.508)	(0.172)
Village FE	YES	YES	YES	YES
Village Pair FE	YES	YES	-	-
Observations	15,714	15,714	14,355	14,355
Number of voucher	1,067	1,067	482	482

*** p<0.01, ** p<0.05, * p<0.1. Robust standard errors clustered by village in parentheses.

Table 6 The effect of observable household characteristics on average demand persistence for SQ-LNS based on endline sub-sample.

	Average sachets/day		**# Weeks with Moving Average>0.4 sachets/day**	
Household size	0.0023	0.0023	-0.011	-0.010
	(0.016)	(0.016)	(0.096)	(0.095)
Asset index	0.21**	0.19**	1.25**	1.12**
	(0.083)	(0.082)	(0.56)	(0.51)
Hunger score	-0.10	-0.083	-0.46	-0.33
	(0.13)	(0.14)	(0.71)	(0.75)
Most of food is home produced	0.30	0.29	0.72	0.61
	(0.23)	(0.23)	(1.52)	(1.49)
≤Half of food is home produced	0.56**	0.56**	2.41*	2.42*
	(0.23)	(0.23)	(1.26)	(1.32)
Low price village	0.22	0.20	0.61	0.42
	(0.27)	(0.27)	(1.39)	(1.43)
Father involvement index		0.14		1.00
		(0.11)		(0.73)
Constant	0.91***	0.91***	5.94***	5.95***
	(0.24)	(0.23)	(1.43)	(1.38)
Observations	230	230	230	230
R-squared	0.034	0.041	0.028	0.040

Robust standard errors clustered by vendor in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

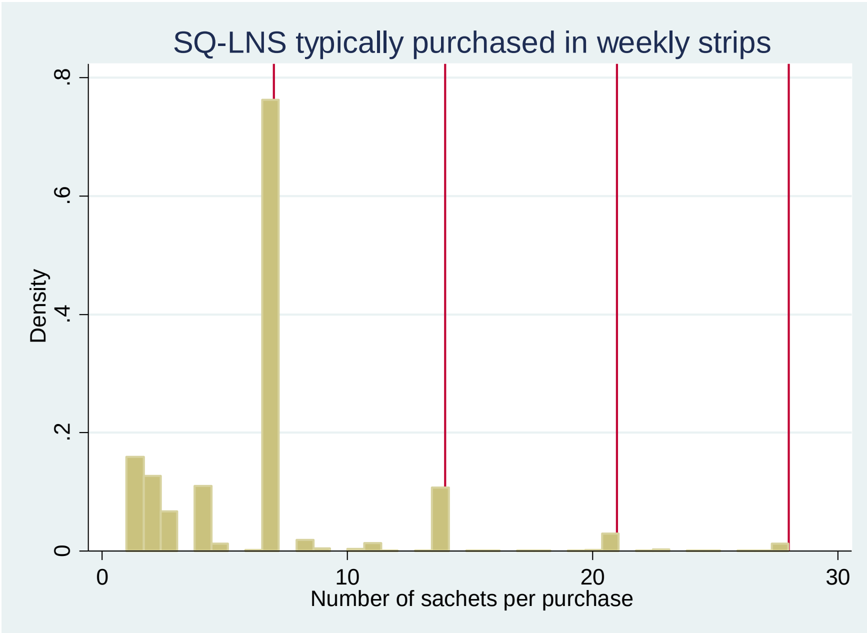

Figure A1 Number of sachets purchased per transaction with modes at multiples of weekly strips

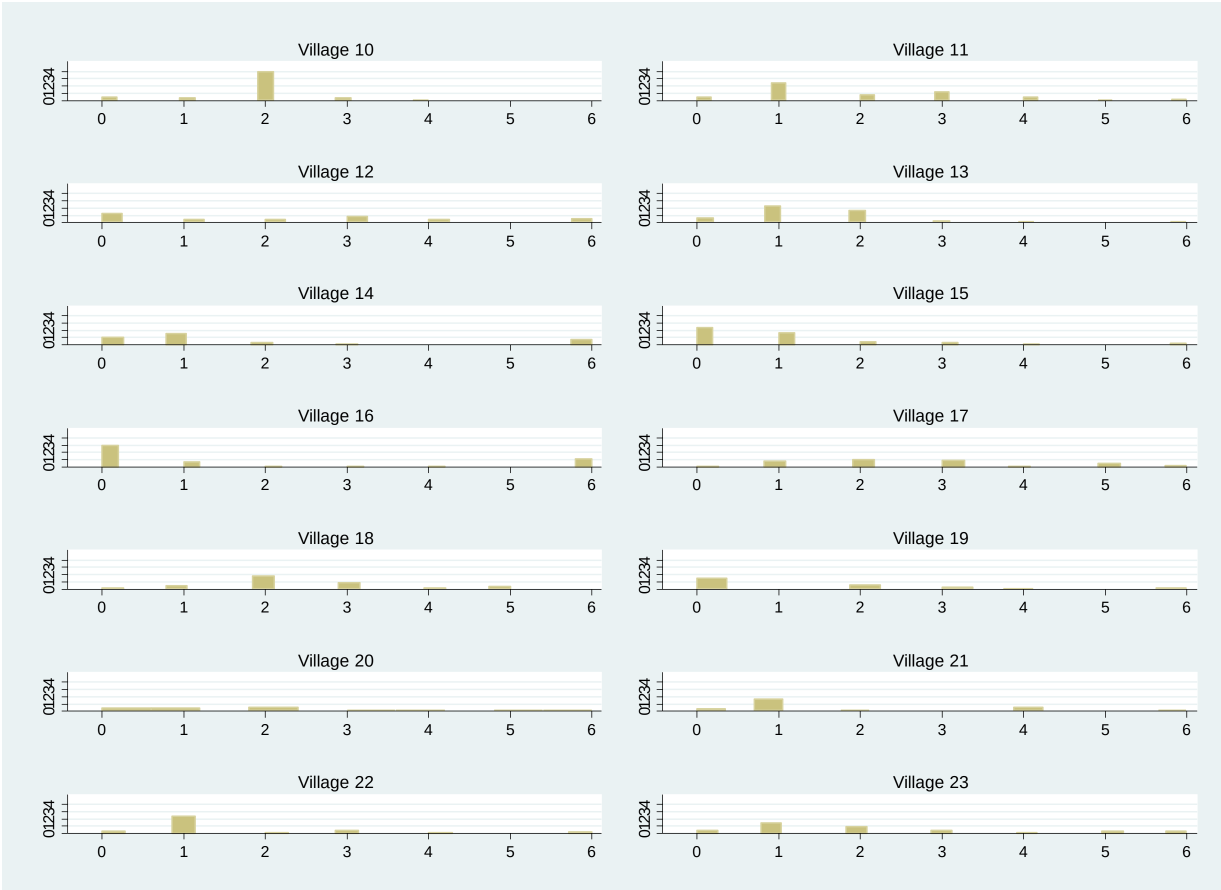

Figure A2 Frequency of purchases by day of week and village (0=Sunday, 1=Monday, …).