Intrahousehold Effects of a Targeted Maternal and Child Nutrition Intervention:
Household Behavior and Spillovers in Ghana

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Abstract
It is common for health and nutrition interventions to target specific members within a household and for evaluations of their effects to focus exclusively on those members. If a targeted intervention introduces a change to a household's utility maximization problem (new information, changes in constraints or prices, etc.) or influences decision-making, households might respond to the intervention in ways that affect the well-being of non-targeted members. In this paper we evaluate household behavioral responses to small-quantity lipid-based nutrient supplements (SQ-LNS) provided specifically to mothers and their infants to prevent undernutrition. We find households responded to the randomized, targeted intervention by increasing their labor supply, particularly among fathers, to fund increased expenditures on food (including nutrient-dense foods like fish, milk, and vegetables) and non-food items. Given higher food expenditures, we then explore whether there was an intrahousehold spillover effect on the nutritional status of non-targeted young children in the household. Overall, the nutritional status of these children was unaffected, but we find evidence of an improvement in linear growth among non-targeted children with relatively taller mothers. Taken together, these findings have potentially valuable policy implications for a country like Ghana that is undergoing a nutrition transition and facing the double burden of undernutrition and growing rates of overweight and obesity. More broadly, our findings underscore the value in collecting sufficient data to rigorously evaluate how households respond to targeted interventions and whether those responses generate intrahousehold spillovers.

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1. Introduction

Nutrition in the earliest stages in the life-cycle – from a woman's pregnancy through her child's second birthday – shapes a child's growth trajectory and developmental potential and, as such, has long-term consequences for human capital acquisition and economic productivity in adulthood (Black et al., 2013; Grantham-McGregor et al., 2007; Hoddinott et al., 2013; Victora et al., 2010; World Bank, 2006). This early, pivotal period in the life-cycle has therefore become the focus of many maternal and child nutrition interventions providing, e.g., conditional cash, health and nutrition information, or supplementation to mothers and/or young children (Ainsworth and Ambel, 2010; Bhutta et al., 2013). Evaluations of the efficacy or effectiveness of these interventions logically center around estimates of their effect on the nutrition, health and development of the targeted household member(s). But household behavior is not static, and if a targeted intervention either introduces changes to a household's utility maximization problem in the form of new information, changes in constraints or relative prices, etc., or influences the decision-making process, the intervention may induce a behavioral response with the potential to affect the well-being (either positively or negatively) of non-targeted household members.

This study explores household behavioral responses to and intrahousehold spillover effects associated with the targeted provision of small-quantity lipid-based-nutrient-supplements (SQ-LNS). SQ-LNS were provided to mothers during pregnancy and the first six months postpartum and to their infants from 6-18 months of age as part of a randomized controlled trial in Ghana designed to test their efficacy vis-a-vis maternal multiple micronutrient tablets and iron-folic acid tablets. We empirically explore whether the targeted provision of SQ-LNS induced changes in household expenditures, paying particular attention to expenditures on nutrient-dense foods. Compared to households in which the mother received either multiple micronutrient tablets or iron-folic acid tablets, we find higher per capita expenditures on food in general and on nutrient-dense foods in particular in households in which the mother and her infant received SQ-LNS. We likewise find higher expenditures on non-food goods and services in these households.

Since both food and non-food expenditures were higher in SQ-LNS households, it is apparent that households were not merely reallocating their budgets between food and non-food items. Therefore, we then consider whether the intervention had a positive effect on the labor income of SQ-LNS households, which would have permitted higher expenditures. Although we find no difference in the income of the target mothers who were directly participating in the trial, total income per capita was higher in SQ-LNS households, as was the income of the husbands of target mothers. These findings provide suggestive evidence that households were funding higher expenditures through a labor response.

Depending on the intrahousehold allocation of food, higher household expenditures on food induced by the targeted intervention had the potential to influence the nutritional status of non-targeted household members. We use anthropometric data on the youngest sibling[2] under age five to explore this potential spillover effect. While we find no overall effect of the targeted provision of SQ-LNS on the siblings' height-for-age, weight-for-age, or body-mass-index-for-age z-scores, we do find improvements in linear growth among the subset of siblings with relatively taller mothers. A child's growth is a reflection of both genetic potential, which is revealed at least in part by maternal height (Addo et al., 2013), and environmental factors that influence growth, including nutrition (Adair, 1999). We find evidence that in households with a young child, maternal height was associated with a larger effect of the targeted intervention on household food expenditures. Possible interpretations of the improvement in linear growth among siblings with taller mothers are therefore that the effect of the intervention on food expenditures was only large enough to induce an observable improvement in linear growth among siblings with taller mothers and/or that better nutrition translated into an observable improvement in linear growth only for those siblings with higher growth potential.

Together, these findings contribute to a small but growing body of literature evaluating spillover effects of targeted maternal and child health and nutrition interventions in developing countries (Adhvaryu and Nyshadham, 2014; Chaudhuri, 2009; Fitzsimons et al., 2014; Kazianga et al., 2014). Each of these studies provided evidence of a spillover effect, though with the exception of Fitzsimons et al. (2014), the behavioral responses to the interventions responsible

[2] "Sibling" here refers to the older brother or sister of the target infant participating in the randomized trial.

for generating the spillover effects are largely peripheral. Using a rich panel dataset, this study takes behavioral responses to a targeted intervention as the point of departure and provides nuanced insight into when and how households changed their behavior in response to the targeted intervention. We then ask whether the changes in household behavior generated observable intrahousehold spillovers on the nutritional status of non-targeted children in the household. The results presented in this study, together with the previous findings in the literature, underscore the importance of assessing not only the effects of an intervention on targeted household members but also the value in collecting data to facilitate an assessment of how households respond to such interventions and whether those responses generate intrahousehold spillover effects.

The remainder of the paper is organized as follows. We begin with background information on SQ-LNS and the randomized controlled trial, followed by a description of mechanisms though which behavioral responses may have been generated. We also present a brief review of relevant literature to set our study within the context of what has previously been discovered on intrahousehold spillovers. This is followed by a description of the data used in the analyses, our empirical strategy, and the results. Finally, we revisit each of the hypothesized mechanisms of behavioral response, present limitations of our findings, and make concluding remarks.

2. Background

Ready-to-use therapeutic foods (RUTF) are fortified, lipid-based food products that are routinely used in the treatment of children with severe acute malnutrition (Arimond et al., 2013; Briend and Collins, 2010). The success of these therapeutic products, which are energy-dense and consumed in large quantities over a relatively short period of time for rehabilitative purposes, has spurred the development of similar products to *prevent* undernutrition, collectively called small-quantity lipid-based nutrient supplements (SQ-LNS), administered at a much lower daily ration (typically 20 g/day, ~118 kcal/day) but with a higher concentration of micronutrients (Arimond et al., 2013; Dewey and Arimond, 2012). SQ-LNS typically contain vegetable fat, peanut paste, milk powder, sugar, and a vitamin-mineral mix, and because the micronutrients in SQ-LNS are embedded in a lipid-rich base, the supplements also provide some macronutrients (fats, protein, and carbohydrates). As described next, the efficacy of SQ-LNS for women and young children was recently evaluated in a randomized controlled trial in Ghana.

2.1 Description of the Randomized Trial

From December 2009 through February 2014, the International Lipid-Based Nutrient Supplement (iLiNS) Project[3] administered a targeted randomized controlled trial in Ghana to evaluate the efficacy of a duo of SQ-LNS products designed for maternal consumption during pregnancy and the first six months of lactation (LNS-P&L) and for consumption in early childhood (LNS-Child) to prevent undernutrition.[4] The catchment area for recruitment of pregnant women into the trial was situated along a busy commercial corridor in the Lower Manya Krobo and Yilo Krobo districts in the Eastern Region of Ghana.

Most households in the semi-urban catchment area have electricity and access to potable water (Adu-Afarwuah et al., 2014). The area also has a large, twice-weekly market and a number of smaller markets, which are very accessible thanks to a reasonably good public transportation system linking the communities along the corridor. Rates of maternal and early childhood undernutrition in this region of Ghana are, in general, comparable to national rates. Among all children under age five in the Eastern Region, 37.9% are stunted (Ghana Statistical Service, 2009).[5] Approximately 73% of children 6-59 months old in the Eastern Region are anemic,[6] and the rate of anemia in women of childbearing age is 58.3% (Ghana Statistical Service, 2009).

Recruitment and enrollment of pregnant women into the trial was done on a rolling basis from December 2009 to December 2011. Women attending select prenatal clinics were approached for potential participation in the trial,[7] and interested women were then screened

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[3] For more information on the iLiNS Project, see: http://ilins.org/

[4] The iLiNS Project also conducted efficacy trials for similar SQ-LNS products in Malawi and Burkina Faso, but sibling anthropometric data are only available for Ghana.

[5] Children with a height-for-age z-score of < -2 SD below the reference population are considered stunted (de Onis and Blössner, 1997). Height-for-age is a cumulative measure of nutritional status and reflects the effect of chronic undernutrition on linear growth (O'Donnell et al., 2008).

[6] Anemia is defined as a hemoglobin concentration in the blood of less than 11 g/dL (Ghana Statistical Service, 2009).

[7] Based on this recruitment mechanism, the women enrolled in the trial were not a random sample of pregnant women in this area of Ghana, which limits the generalizability of our results. We discuss this issue further when we address the limitation of the study.

to determine their eligibility.[8] Eligible and willing women were then formally recruited into the study and randomized into one of the trial's three equally-sized arms in which women received either (1) daily iron-folic acid tablets throughout pregnancy, the current standard of prenatal care in Ghana, and a placebo (low-dose calcium tablet) during the first six months postpartum, (2) daily multiple micronutrient tablets during pregnancy and the first six months postpartum, or (3) LNS-P&L during pregnancy and the first six months postpartum; the infants of women randomized into the LNS-P&L group also received LNS-Child from 6-18 months of age. The infants of women randomized into the iron-folic acid or multiple micronutrient tablet groups did not receive any supplementation. Table A1 in the appendix shows the nutrient composition of each SQ-LNS product alongside the nutrient composition of the multiple micronutrient and iron-folic acid tablets.

At enrollment, each woman received instructions on how to take her assigned supplement and was told, "Do not forget to eat meat, fish, eggs, fruits and vegetables whenever you can. You still need these foods even if you take the supplement we have given you." Over the course of the maternal portion of the intervention during pregnancy and the first six months postpartum, all women in the trial, regardless of treatment group, were visited by project staff every two weeks to deliver supplements and collect data on morbidity and adherence to the study protocol. The nutrition message was repeated to all women at a laboratory visit at 36 weeks of gestation. After the birth of the women's infants, staff made weekly home visits to deliver supplements (if applicable) and collect morbidity and adherence data on the infants. A message about the importance of feeding the infant diverse, nutritious foods as well as continuing to breastfeed was also communicated to all women, regardless of treatment group, when their infants were six months old. Beyond delivery of different supplements, the frequency of contact with the households by iLiNS staff and the content of those visits were, by design, very uniform across the treatment groups.

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[8] Eligibility requirements were (1) at least 18 years of age, (2) not more than 20 weeks of gestation (determined by dating ultrasound), (3) possession of an ante-natal card issued by the Ghana Health Service, (4) complete preliminary ante-natal examination, (5) HIV negative or unknown status, (6) no chronic diseases requiring frequent medical attention, (7) residence in the Manya Krobo or Yilo Krobo districts throughout the intervention, and (8) prepared to sign an informed consent and receive home visitors. Women with known peanut or milk allergies, women participating in concurrent trials, and women with severe illnesses warranting hospital referrals were also excluded from the study.

Statistical analyses of the effect of the intervention on birth outcomes[9] showed that providing women with SQ-LNS during pregnancy increased average birth weight by 85 grams (2.9%) relative to women who received iron-folic acid tablets, though there was no difference in birth weight relative to the women who received multiple micronutrient tablets (Adu-Afarwuah et al., 2014). The analyses also demonstrated statistically significant heterogeneity in the effect of SQ-LNS on birth outcomes by parity. Among first-time mothers, the provision of SQ-LNS compared to iron-folic acid tablets and compared to multiple micronutrient tablets had a large impact on birth weight, length and head circumference and decreased the incidence of low birth weight (birth weight < 2500 grams), whereas there was no effect in multiparous mothers. The analyses presented in this paper broaden the scope of potential treatment effects of the intervention by exploring household behavioral responses and the nutritional status of non-targeted siblings.

2.2 Hypothesized Mechanisms of Behavioral Response

There are several mechanisms or pathways through which households might have responded to the targeted intervention in ways that could have influenced expenditure patterns and/or the supply of labor and, ultimately, the nutritional status of non-targeted household members. We describe them here and, after presenting our results, return to them to discuss the likelihood of each in the context of this intervention.

Perhaps the most obvious is an income effect. If households were able to liquidate SQ-LNS in an informal market, the money could have been used to fund additional consumption. And even if households were not selling SQ-LNS, households in which the mother and infant received SQ-LNS were different from those in which the mothers received tablets in that SQ-LNS contributed free additional calories to the household's total food basket. This transfer of calories may have offset the household's need to purchase those calories, thereby increasing the household budget.

Another hypothesis relates to the potential effects of SQ-LNS on maternal and infant health. The demands of a newborn on a mother's time are great, which likely has repercussions for how other household members can use their time (e.g., if the mother is busy tending to her

[9] Analyses of maternal outcomes and of the growth and cognitive development of the target infant are forthcoming.

infant, it might fall on other household members to visit the market, clean, prepare food, manage the household business, etc.). The demands on a mother's time are likely magnified if her infant is unhealthy, so if mothers and infants who consumed SQ-LNS were generally less sick than those in the non-SQ-LNS group, this may have, in essence, freed up additional household time, allowing for an increase in the household's labor supply.

A final hypothesis is that the way SQ-LNS were consumed relative to the multiple micronutrient and iron-folic acid tablets acted as a primer that put food and nutrition at the forefront of mothers' minds, which in turn influenced their judgments and decisions surrounding food. Priming is a theory of cognitive functioning in psychology used to describe an implicit memory process in which previous experience with a stimulus generates heightened sensitivity to a subsequent related stimulus (Henson, 2003; Schacter and Buckner, 1998). Mothers were advised to mix SQ-LNS with food and were told at the onset of the trial to eat foods like eggs, fruits, and vegetables whenever possible. The same message was conveyed again at 36 weeks of gestation and again when their infants began consuming SQ-LNS at six months. While mothers in the group receiving tablets were also given the same information about feeding themselves and their infants nutritious foods, perhaps that act of fortifying food with SQ-LNS day-in and day-out had a priming effect on mothers in the SQ-LNS group, which made this message (and food in general) more salient and influenced the way mothers in the SQ-LNS group thought about the role of food in the production of health.

2.3 Behavioral Responses and Spillover Effects

The findings in this study fit into a nascent body of literature that has demonstrated the potential for behavioral responses and intrahousehold spillover effects associated with targeted maternal and child health and nutrition interventions in developing country settings. For instance, Adhvaryu and Nyshadham (2014) found that *in utero* exposure to an iodine supplementation program in Tanzania increased the probability the child was later vaccinated against polio, diphtheria, and measles. The study also found evidence of an intrahousehold spillover effect: older siblings of the infants exposed to iodine supplementation were also more likely to be vaccinated. The authors attributed the spillover effect to an intrahousehold resource reallocation among siblings stemming from a parental preference for equity among their children.

Using a randomized block design, Kazianga et al. (2014) evaluated the spillover effects of two school-feeding programs on the nutritional status of preschool-aged siblings in rural Burkina Faso and also found evidence of a spillover effect. A year into a 'take home rations'[10] school feeding program, the authors found a positive effect on the weight-for-age z-scores (WAZ) of preschool age siblings of children in treated schools, although height-for-age z-scores (HAZ) were unaffected. The other school feeding program, school meals, had no effect on the WAZ or HAZ of the younger siblings. The authors attributed the spillover effect of the take home rations program to intrahousehold food redistribution, which may have been more easily achieved under the take-home rations program relative to school meals.

In another study, Chaudhuri (2009) used data from a targeted, quasi-controlled maternal and child health-family planning program in rural Bangladesh to estimate intrahousehold spillovers on the health of elderly household members. With average baseline body mass indices (BMI) of both men and women over age 60 below what is considered a healthy BMI, the study found a statistically significant increase in the BMI of non-targeted elderly women in the household. The author provided some limited evidence suggesting the spillover was less due to an income effect (a freeing-up of household resources as a result of public health inputs provided to targeted members) and likely more attributable to a combination of a household public goods effect (information on hygiene, women's health, and nutrition provided by the program shared among household members) and a contagion effect (less illness and infection among household members).

Finally, Fitzsimons et al. (2014) evaluated household behavioral responses to a targeted cluster randomized intervention in Malawi that provided information related to infant feeding practices[11] to mothers with a child under six months. The study found households who received the information treatment increased their consumption of proteins, fruits, and vegetables.

[10] Take home rations of 10kg of cereal flour were given to female students on a monthly basis conditional on a 90% school attendance rate.

[11] Exclusive breastfeeding was emphasized in all visits, and later visits also included information on appropriate complementary foods including the importance of dietary diversity and preparation techniques to minimize nutrient loss.

Paternal labor supply[12] also increased in treated households, suggesting the new information about child health stimulated a labor response in order to fund higher food consumption. The study also showed that the information treatment not only improved the height-for-age of targeted children but also improved the dietary quality (increased intake of protein-rich foods) of older siblings of the targeted children, though the nutritional status of the siblings was not affected. The present study is, in some ways, quite similar to Fitzsimons et al., but whereas their targeted treatment was the provision of information related to health and nutrition that might have had more obvious pathways of intrahousehold spillover (i.e., a mother better informed about how to feed her infant may also apply that knowledge to improving the diets of other household members), we evaluate household responses to simply providing a food-based supplement with a very low-intensity educational component that was uniform across groups.

This study makes several contributions to this emerging body of literature. First, we provide new evidence on the potential for spillover effects associated with targeted nutrition interventions. We also use detailed data on household income and expenditures to evaluate household behavioral responses to the targeted intervention along dimensions that could generate spillover effects on the nutritional status of non-targeted household members. Finally, the panel data structure enables us to look at heterogeneity in effects over the course of the intervention, which is particularly relevant in this case since the intervention spanned several years and encompassed periods of distinct transition in the household from pregnancy to the addition of a new infant and through the early life of the infant into toddlerhood.

3. Data

3.1 Summary Statistics

The behavioral response outcome variables used in this study came from a household expenditures questionnaire and a socioeconomic and demographics characteristics questionnaire. The household expenditures questionnaire, which was administered three times to a randomly selected subsample of approximately 60% of the households participating in the trial, was subdivided into food expenditures (based on a 1-week recall period), frequent non-food expenditures (1-month recall), and infrequent non-food expenditures (12-month recall).

[12] Paternal labor supply was measured as whether the father had two or more jobs.

All expenditures were converted from Ghana cedis to 4th quarter 2011 USD and expressed as per capita[13] daily amounts.

Income data for each household member were collected as part of the demographic and socioeconomic characteristics questionnaire, which was administered to the full sample of households participating in the trial four times during the intervention. The questionnaire respondent, who was the target mother participating in the randomized trial, was asked to report the income each household member typically received from his/her primary work. From the household roster of income information, we focus on the effects of the targeted intervention on the income of the target mother who directly participated in the trial, her husband,[14,15] and total household income per capita.

Finally, to assess intrahousehold spillovers, we used anthropometric data that were collected three times during the intervention from the youngest sibling under age five in the household. The criterion for inclusion in the sibling subsample was that the child shared the same mother as the target infant and that the sibling was less than 60 months old at maternal enrollment into the trial. In our analysis we used z-scores of the anthropometric measures, which enables the comparison of an individual child's anthropometric measurements (length/height and weight) to children of the same age and gender in the reference population (O'Donnell et al., 2008).[16, 17] We calculated z-scores of height-for-age (HAZ), weight-for-age (WAZ) and BMI-for-age (BMIZ) using WHO Anthro and WHO2007, Stata macros from the World Health Organization based on the updated WHO child growth standards and WHO reference

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[13] Expenditures per adult equivalent rather than per capita may be a better representation of how much a household spent relative to other households with different demographic compositions. Missing age data and complications in the way the household roster was updated between rounds prevent us from calculating accurate per adult equivalents in this case.

[14] Informal unions between the target mother and a man were very common in the sample. These unions were informal in the sense that they had not received civil or traditional recognition, but for the purposes of this study we group men married to the target woman and men in an informal union with the target women together and call them husbands.

[15] Households are excluded from analyses of paternal income in cases where the target mother did not have a husband.

[16] The z-score is calculated as the difference between the child's value (weight or height) and the median value of the reference population divided by the standard deviation of the reference population, where the reference population is of the same gender and age.

[17] The reference population is a sample of 8,500 children from Brazil, Ghana, India, Norway, Oman, and the United States who were weighed and measured between 1997 and 2003 by the World Health Organization to generate growth curves based on a single international standard (World Health Organization 2009).

2007, respectively.[18,19] Because these macros do not calculate weight-for-height z-scores (WHZ) for children over 60 months (and therefore WHZ is missing for children who aged past 60 months at follow-up anthropometric visits), WHZ was not included in this analysis. In four cases, siblings were recorded as losing height between rounds; these children were excluded from analyses of HAZ and BMIZ. An additional three biologically implausible z-scores were also excluded.[20]

The timeline in Figure 1 shows the planned timing of enumeration relative to maternal enrollment into the trial and the birth of the infant, although as explained in the next section, data were often collected weeks or months after the scheduled date. The first round of observations for each of the outcome variables described above, along with other variables that characterize the study population, are summarized in Table 1. However, the planned first round of socioeconomic and sibling anthropometric data collection at enrollment into the trial was delayed for a few weeks to a few months for some households, so true baseline values are not available. Among variables that may not reflect baseline conditions, those from the socioeconomic and demographics questionnaire (all maternal characteristics, household demographics, and household and paternal income) were collected within two weeks of randomization for 61% of households, 75% were collected within four weeks, and 89% were collected within eight weeks. The baseline food insecurity data were collected within two weeks of randomization for 56% of households, 72% were collected within four weeks, and by eight weeks after randomization food security data had been collected for 88% of households. Expenditure data were collected within two weeks after randomization for 13% of households, 37% were collected within 4 weeks, and 67% within 8 weeks. Finally, 22% of the sibling anthropometric measures were taken within two weeks of randomization, 37% were within four weeks, and 59% were measured within eight weeks. Some variables such as maternal height, BMI, and age were recorded on the day of enrollment and others are time-invariant

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[18] WHO Anthro calculates z-scores for children under 60 months, and WHO2007 calculates z-scores for children 60 months and older. Since some siblings in the sample aged past 60 months during the intervention, both macros were needed to generate z-scores for these children across all three rounds.

[19] Available for download at: http://www.who.int/childgrowth/software/en/ (WHO Anthro) and http://www.who.int/growthref/tools/en/ (WHO2007).

[20] Biologically implausible z-scores are outside the range -6 to 6 for HAZ, -6 to 5 for WAZ, and -5 to 5 for BMIZ (Mei and Grummer-Strawn, 2007) and can be attributed to improper measurement or data entry error.

(e.g., maternal education and sibling gender) or can be back-calculated to enrollment (e.g., sibling age). Variables that reflect baseline conditions are marked with a superscripted 'b' in Table 1.

Several variables merit comment. Maternal, paternal, and household income are based on self-reported income typically received from the household member's primary work in the previous 12 months. For reference, the most common occupation among the target women in the sample was petty trade (48%), while approximately 20% reported no income, and just 1% identified farming as their primary work. The husbands of target mothers in the sample were drivers/driver's assistants (20%), artisans (primarily self-employed carpenters and masons) (19%), shop owners (8%), mechanics (7%) and teachers (6%). The household asset index was constructed using principal components analysis based on ownership of a set of assets, housing characteristics, and water and sanitation sources (Vyas and Kumaranayake, 2006) such that a higher score indicates a better relative socioeconomic status.[21] Finally, the HFIA score, a measure of household food insecurity[22], indicates that, on average, households in the sample were food secure, with an average score of 2.6 on a scale of 0-27.

Turning to sibling characteristics, height-for-age is a cumulative measure of nutritional status and reflects the effect of long-term undernutrition on linear growth (O'Donnell et al., 2008). Children with a HAZ of less than -2 standard deviations from the median value in the reference population are considered stunted (de Onis and Blössner, 1997). The average HAZ of the siblings in our sample at first measurement was -1.35 standard deviations from the median reference child, which matches the average HAZ among all children under five in the Eastern Region of Ghana (Ghana Statistical Service, 2009).[23]

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[21] The assets included in the index were furniture, radio, stove, refrigerator, television, and car. Housing characteristics and water and sanitation sources included in the index were flooring material, electricity, primary source of drinking water, and toilet facility.

[22] The Household Food Insecurity Access (HFIA) Scale was developed by USAID's Food and Nutrition Technical Assistance (FANTA) project (Coates et al., 2007). Each household was assigned a score between 0-27 based on how frequently the household experienced each of nine food insecurity conditions in the four-week period prior to the interview; a higher score indicates higher food *in*security.

[23] Note that the age distribution in our sample is slightly different than the age distribution of children under five who were surveyed as part of the Demographic and Health Survey (DHS). The DHS included more children under age two and fewer children between 2-5 years old.

Weight-for-age reflects body mass relative to age and can reflect both current and cumulative nutritional conditions (de Onis and Blössner, 1997). Children with a WAZ less than -2 standard deviations from the median value in the reference population are classified as underweight. The average WAZ in the sibling sample was -0.78 at first measurement, slightly lower that the average WAZ of -0.6 among children under five in the Eastern Region (Ghana Statistical Service, 2009).

Finally, BMI-for-age, a measure of body mass relative to height, is less-commonly used to assess the nutritional status of children under five, but since our sample included children who aged beyond 60 months during the intervention period, we include it in the analysis. The average BMIZ at first measurement in the sibling sample was 0.12. BMIZ cut-offs are established for both overnutrition and undernutrition and have different cutoff points for children under age five and children ages 5-19. Under age five, a child with a BMIZ of > 3 is categorized as obese, while a BMIZ < -2 is an indicator of wasting (World Health Organization, 2008). For children five years and older, a BMIZ of > 2 is an indicator of obesity while a BMIZ < -2 is an indicator of thinness.

Figure 2 presents density estimates of sibling z-scores at first measurement. Approximately 28% of the siblings were stunted at first measurement, lower than the rate of stunting in the Eastern Region of Ghana among children under five, which was 37.9% in 2008 (Ghana Statistical Service, 2009). Rates of underweight at first measurement were slightly higher than the 2008 regional rate: 11% in the sibling sample compared to 8.7% in the Eastern Region. Less than 2% of the siblings would be considered wasted or thin according to their BMIZ, while at the other end of the spectrum, less than 1% of the siblings would be classified as obese.

Table 2 compares first round maternal, household, and sibling characteristics by treatment group. Bearing in mind that the first round of data were collected after first receipt of supplement for most households, we find no statistically significant difference in balance across treatment groups, but given the limitations of the data, we cannot test whether the groups were similarly balanced at baseline.[24]

3.2 Potential Data Complications

Two features of the data – the timing of enumeration and attrition - merit consideration because they raise concerns about the ability to use the data to draw valid causal inferences. In particular, each questionnaire was scheduled to be administered at baseline and, depending on the specific questionnaire, again at two or three specific windows of time for follow-up during the trial as depicted in Figure 1. However, scheduling issues,[25] primarily, meant questionnaires (including the planned baseline) were often administered weeks or months after the scheduled window, and some visits were missed entirely. Therefore, we have a short, unbalanced panel of observations for each household or sibling, but the timing of each follow-up observation relative to, e.g., the birth of the target infant, varies substantially in the data. Furthermore, the baseline round was, on average, delayed for 3 weeks after randomization for the income data, 7.5 weeks for the expenditure data, and 8.5 weeks for the sibling anthropometric measurements. Because of delays in questionnaire administration, instead of observing all households/siblings at set time points (at six months after the birth of the target infant, for example), we observe some households/siblings at six months after the birth, another group during the seventh month after the birth, another during the eighth month, etc. The distribution of timing of enumeration at each planned round relative to the birth of the target infant is shown in Figure 3.

It is possible that delays in enumeration were endogenous. Endogeneity in the timing of enumeration could occur if, for example, home visits to administer questionnaires were continually rescheduled for some particularly entrepreneurial households who were often away from home working, in which cases delays in enumeration were at least partly attributed to the

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[24] For data coming from the socioeconomic and demographics questionnaire (all maternal characteristics not marked with a superscripted 'b', household demographics, and household and paternal income), first-round data were collected within the two-week window after enrollment for 61% of the sample, and tests for differences in means for this subgroup in which data were collected within two weeks of enrollment again show no difference between the SQ-LNS and non-SQ-LNS group.

[25] Scheduling issues included difficulty scheduling a time to administer lengthy socioeconomic questionnaires, frequent rescheduling of visits when respondents were not home/available, and scheduling conflicts with the anthropometry team in the case of the sibling anthropometric measurements.

household's entrepreneurial spirit, which is also likely associated with our outcomes of interest and may be influenced by the treatment. If timing of enumeration was affected by the treatment, including it in our regression models could bias the estimated effects by capturing some of the impact (Duflo et al., 2008). Although (unreported) regressions of the number of months from the birth of the target infant to enumeration on the treatment indicator variable indicate that, for each outcome variable, variation in the timing of enumeration was balanced between treatment groups, this does not ensure the delays were random. We address this concern with a series of robustness checks as described in the empirical strategy section.

Putting aside the issue of variation in the timing of enumeration, the panel is also unbalanced in the familiar sense of having completely missing observations for some households at various rounds of data collection and for specific questionnaires. Attrition rates at each planned round of data collection (where Round 1 is the planned baseline) are summarized in Table 3. Patterns of attrition included both intermittent missingness and permanent drop-out.

There was substantial attrition in both the SQ-LNS and non-SQ-LNS groups at each follow-up. Identification of the causal effects of SQ-LNS on our outcomes of interest relies on the group who did not receive SQ-LNS as a counterfactual. That is, the non-SQ-LNS group tells us what the outcomes of the group who received SQ-LNS would have been had they not received the treatment.[26] The randomization process establishes a credible counterfactual group, but if attrition was not random, the remaining non-SQ-LNS group may not be a valid counterfactual to the remaining SQ-LNS group, in which case our estimated effects would be biased. For each outcome variable used in this study, we test for differences in the distribution of the first-round value of the outcome variable between the remaining SQ-LNS and non-SQ-LNS groups at each follow-up. The exact p-values from Kolmogorov-Smirnov tests for equality of the SQ-LNS and non-SQ-LNS distributions are reported in Table 4.

The test results show that the distribution of the first round values of each outcome variable are not statistically significantly different between non-attritors in the SQ-LNS group and the non-attritors in the non-SQ-LNS group, implying that despite attrition, the non-SQ-LNS

[26] Or, more accurately in this case, had they received either iron folic-acid or multiple micronutrient tablets.

group should still serve as a good counterfactual. However, the p-value of .1 on the test statistic for a difference in the distributions of the natural log of per capita daily household income at the second round for the SQ-LNS and non-SQ-LNS group is potentially concerning. A t-test for the difference in means shows that there is no difference in the average first round values of the log of per capita daily household income between the groups observed in the second round (p = .6). Nevertheless, the results related to household income should be interpreted with this potential caveat in mind.

4. Empirical Strategy

As previously described, mothers and infants were randomized into three groups, one in which the mother and her infant received SQ-LNS, one in which the mother received multiple micronutrient tablets, and one in which the mother received iron-folic acid tablets. We combine those who received either form of tablets into one group and compare them to those who received SQ-LNS. Identification of the causal effects of targeted maternal and infant provision of SQ-LNS on household behavioral responses is based on random assignment to the SQ-LNS and non-SQ-LNS treatment groups. For $j = 1, \ldots, H$ households and $r = 1, 2, 3$ rounds of data collection,[27,28] we estimate the treatment effect on our behavioral response variables with the following random effects specification (Rabe-Hesketh and Skrondal, 2012):

$$y_{jr} = \beta_1 LNS_j + \beta_2 t_{jr} + \delta X_j + \gamma I_{jr} + \alpha_j + \varepsilon_{jr}. \quad (1)$$

The dependent variable, y_{jr}, is the log of the outcome of interest (expenditures or income) for household j at round r. LNS_j is an indicator variable equal to one if the mother-infant dyad in household j was randomized to receive SQ-LNS and zero otherwise. The variable t_{jr}, a control for the timing of enumeration, is the number of months from the birth of the target infant to

[27] We also ran all regressions with time marked by months from the birth of the target infant instead of round of data collection. Setting up the models this way yielded very similar results.

[28] For expenditures on food and frequently purchased non-food goods and services, we include all three rounds of data collection since the first round occurred at least a few weeks after randomization for most households and therefore adds information on household behavioral responses to SQ-LNS during pregnancy and early postpartum. The recall period for infrequent non-food expenditures (past 12 months) extended into the pre-treatment period for all households at the first round of data collection, so we exclude the first round of data collection for analyses of infrequent non-food expenditures. For income, we omit the first round of observations since the outcome variables were all based on income typically received from household members in their primary work in the past 12 months, and the first round of income data were collected within the two weeks of randomization for more than half of the households in the sample. In the follow-up rounds, the reference period for the questions on income was since the last visit in which income data were collected.

enumeration.[29] To improve the precision of our estimates, we also include a vector of time-invariant covariates, X_j, which are season and year of maternal enrollment into the intervention, primary language spoken in the household, maternal gestational age at enrollment, maternal height, and maternal years of education. We also control for enumerator effects with a set of indicator variables in the vector I_{jr}. The parameter α_j is a household-level random effect, and ε_{jr} is an idiosyncratic error. To account for correlation in the error over time for a given household, we cluster the standard errors at the household level.[30]

As previously noted, timing of enumeration, t_{jr}, is potentially endogenous. We confirm our estimated treatment effects are robust to controlling for timing of enumeration in two ways. First, we replace the timing of enumeration variable with a set of dummy variables indicating round of data collection, which is exogenous to households. We also instrument for timing of enumeration using the number of households enrolled in the trial per enumerator. Given the rolling enrollment design of the intervention, there were very few households enrolled in the trial early on, and the ratio of households to enumerators was low. As more households were enrolled, additional enumerators were hired on, but not at a rate to maintain the households per enumerator ratio, so this ratio also increased, as depicted in Figure 4. Towards the end of the trial as households were completing the intervention but no new households were being enrolled, the ratio again decreased.

It is possible the effects of treatment on household behavior were not constant over the course of the intervention. If, for instance, perceived costs or benefits associated with consuming SQ-LNS changed over the course of the trial (during maternal consumption of SQ-LNS vs consumption by her infant or as mothers gained more experience with the supplement, for example) or if the mechanism generating the behavioral response was only relevant at certain stages in the trial (e.g., during pregnancy or after the birth of the infant). We explore whether the effect of treatment on our behavioral response variables varied over the course of

[29]In cases where no date of birth data were available for the target infant because of stillbirth, miscarriage, loss to follow-up at birth, etc., we estimate the date of birth using the mother's enrollment date, her gestational age at enrollment, and the average gestational age at delivery in the sample.

[30] Clusters should be defined broadly enough to account for variation in both regressors and errors (Cameron and Miller, *Forthcoming* 2015). Given that the study site is relatively small and quite homogeneous, there does not exist a readily definable higher level of household groupings that could be used to define clusters.

the intervention by interacting the treatment indicator, LNS_j, with a quadratic[31] time trend, t_{jr} and t_{jr}^2, where t_{jr} is the number of months from the birth of the target infant to enumeration as in equation 2.

$$y_{jr} = \beta_1 LNS_j + \beta_2 t_{jr} + \beta_3(LNS_j * t_{jr}) + \beta_4 t_{jr}^2 + \beta_5(LNS_j * t_{jr}^2) + \delta X_j + \gamma I_{jr} + \alpha_j + \varepsilon_{jr}. \quad (2)$$

Statistically significant coefficients on the interactions between treatment and time will indicate heterogeneity in the magnitude of the effect over the course of the intervention.

Turning to sibling anthropometric outcomes, we estimate sibling spillover effects of the targeted intervention on BMI-for-age z-score (BMIZ), weight-for-age z-score (WAZ), and length/height-for-age z-score (LAZ) with the following random effects model:

$$y_{ir} = \beta_1 LNS_i + \beta_2 t_{ir} + \delta X_i + \gamma A_{ir} + \alpha_i + \varepsilon_{ir} \quad (3)$$

for $i = 1, \dots N$ siblings and $r = 1, 2, 3$ rounds of data collection. As before, LNS_i is an indicator variable equal to one if sibling $i's$ mother and baby sister/brother were randomized into the SQ-LNS arm of the trial and zero otherwise. t_{ir} is the number of months from the birth of the target infant to sibling measurement. Baseline covariates included in the vector X_i are sibling age at maternal enrollment into the trial, sibling gender, and maternal gestational age at enrollment, height, BMI at enrollment, and years of education. Controls for the anthropometrists who weighed and measured the siblings are captured in A_{ir}. Finally, α_i is a sibling-level random effect, and ε_{ir} is an idiosyncratic error term. As in the behavioral response analyses, we also confirm the robustness of the estimated spillover effects when t_{ir} is included in the regression model by (1) controlling for round of measurement instead of exact timing of enumeration, and by (2) instrumenting for the timing of enumeration using the number of enumerators per sibling.

To estimate the spillover effect of the intervention on child growth over time, we estimate the following random effects model:

$$y_{ir} = \beta_1 LNS_i + \beta_2 t_{ir} + \beta_3(LNS_i * t_{ir}) + \beta_4 t_{ir}^2 + \beta_5(LNS_i * t_{ir}^2) + \delta X_i + \gamma A_{jt} + \alpha_i + \varepsilon_{ir} \quad (4)$$

which includes a quadratic time trend measured in months from the birth of the target infant to sibling measurement, t_{ir} and t_{ir}^2, interacted with the treatment indictor.

[31]We used nonparametric lowess regression to explore the relationship between the predicted outcome variables for the SQ-LNS and non-SQ-LNS groups and determined a quadratic fit sufficiently captures the effect over time.

5. Results

5.1 Effect on Household Expenditures

We begin with the effect of the provision of SQ-LNS to the target mother and infant on household expenditures. Figure 5 summarizes unconditional expenditures by round of data collection and by treatment group. Per capita daily household expenditures on food were statistically significantly higher in the SQ-LNS group at the second round (p<.01). Expenditures were also higher in the SQ-LNS group in the second round (p<.01) on a subset of food classified as nutrient-dense, which includes animal-source foods, fruits (excluding plantains), vegetables (excluding starchy vegetables such as cassava and yam), pulses, and nuts (World Health Organization, 2010).[32] It should be noted that reported food expenditures did not account for home-produced food, but given the semi-urban setting of the trial and the rarity of engagement in agriculture beyond small home gardens in the sample, the role of own-production is not likely to be influential. Finally, there were no differences in average frequent or infrequent non-food expenditures between the SQ-LNS and non-SQ-LNS groups.

We report the estimated effects of SQ-LNS on the log of household expenditures in Table 5. Based on the estimates that control for the timing of enumeration relative to the birth of the target infant, SQ-LNS provided to a mother during pregnancy and the first six months postpartum and to her infant from 6-18 months of age significantly increased per capita daily total food expenditures (column 1), nutrient dense food expenditures (column 4), and frequent and infrequent non-food expenditures (columns 7 and 10, respectively) relative to households in which the mother received multiple micronutrient or iron-folic acid tablets. Given that the dependent variable is log-transformed, the coefficients can be interpreted as approximate percentage changes. Taking the exponential of both sides of the estimated equation,[33] the coefficient estimates imply that targeted SQ-LNS supplementation increased household per capita daily food expenditures by 7.5% and increased per capita daily expenditures on nutrient-dense foods by 8.3%. SQ-LNS also increased expenditures on frequently purchased non-food

[32] A list of all foods included in each category is available in Table A2 in the appendix.
[33] With a log-transformed dependent variable and a dichotomous treatment variable, the effect of the treatment is calculated by taking the exponential of both sides of the equation and finding the difference when evaluated at treatment = 1 and treatment = 0. That is, exp($\hat{\beta}$)-1, where $\hat{\beta}$ is the estimated coefficient on the treatment variable (Halvorsen and Palmquest, 1980).

goods and services by 12.6% and on infrequently purchased goods and services by 10.7%. Based on average expenditures in the first round of data collection, these percentage increases imply that relative to non-SQ-LNS households, the SQ-LNS households were, on average, spending approximately $0.10 more per person per day on food and $0.06 more per person per day on nutrient-dense foods. For non-food expenditures, the estimated percentage increases equate to approximately $0.08 more per person per day for both frequent and infrequent expenditures.[34]

If the timing of enumeration was endogenous, including it as a control may bias our estimated treatment effects. We confirm our results are robust to this control in two ways. First, we replace the control for timing of enumeration as measured by months from the birth of the target infant with round of data collection, which is exogenous to households. These results, shown in columns 2, 5, 8, and 11 of Table 5, are very similar both in magnitude and statistical significance to the estimates that control for timing of enumeration. We also instrument for the timing of enumeration using the ratio of households per enumerator. Based on the Kleibergen-Paap F-statistics presented in columns 3, 6, 9, and 12 of Table 5, we reject the null of weak identification using the households per enumerator variable (Stock and Yogo, 2005).[35] The two-stage least squares (2SLS) coefficient estimates on the treatment variables are also very close to the estimates obtained by directly control for timing of enumeration. Together, these checks provide confirmation that including timing of enumeration does not introduce any substantial bias into our estimated effects and can be used directly when estimating treatment effects.

In the context of the randomized trial in Ghana, where households are largely food secure, dietary diversity is poor, micronutrient deficiencies are common, and overweight and obesity are increasing problems (Abrahams et al., 2011; World Bank, 2013), it is insightful to take a more disaggregate look at household food expenditures. Tables 6 and 7 break down the

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[34] This set of results is sensitive to controlling for enumerator. Without controlling for enumerator effects, the coefficient estimate on food expenditures is .06 ($p<.1$), the coefficient on nutrient-dense food expenditures is .065 ($p<.1$), and the coefficients on the non-food expenditure categories are not statistically significant.

[35] The critical values suggested by Stock and Yogo (2005) are calculated for the Cragg-Donald F statistic and are appropriate under i.i.d. errors. Staiger and Stock (1997) suggest caution with applying these critical values to the Kleibergen-Paap F statistic in the presence of non-i.i.d. errors or to alternatively apply the rule of thumb that the F statistic should be greater than 10 to reject the null of weak identification.

effect of SQ-LNS on expenditures on each of seven nutrient-dense food categories and seven other food categories, respectively.[36] The results show targeted maternal and infant provision of SQ-LNS had a statistically significant positive effect on expenditures on poultry and eggs, fish, milk, and vegetables. Expenditures on some categories of non-nutrient-dense food, including cereals, oils and fats, starchy staples, spices, and sugar and sweets, were also statistically significantly higher among the SQ-LNS group.

Finally, we explore heterogeneity in the timing of the effect of the targeted intervention on household expenditures relative to the birth of the target infant and find statistically significant heterogeneity in the effect over time for food and nutrient-dense food expenditures, as shown in Table 8. These results are presented graphically in Figure 6. As is evident in the top two panels of the figure, the average effect of SQ-LNS on food and nutrient-dense food expenditures peaked when the target infant was around five or six months old. After that point, the effect dampened, though continued to be statistically significant, until the infant was around eleven months old, and after that time the effect of SQ-LNS on food and nutrient-dense food expenditures was not statistically different from zero. As is shown in columns 3 and 4 of Table 8 and the bottom panels of Figure 6, there was no statistically significant heterogeneity over time in the effect of SQ-LNS on non-food expenditures.

5.2 Effect on Income

Given the statistically significant increase in expenditures in the SQ-LNS group, the next question logically centers on how households funded the increased expenditures. Since both food and non-food expenditures were higher in the SQ-LNS group, this suggests households were not simply reallocating their budget shares between food and non-food items. Regressions of food as a percentage of total expenditures (results available in Table A3 of the appendix) confirm that there was no difference in the percentage of total expenditures allocated to food between households in the SQ-LNS and non-SQ-LNS groups. We therefore turn to an analysis of the effect of SQ-LNS on labor income to explore whether a difference in income among SQ-LNS households might have made the higher expenditures possible. In

[36] For some households, expenditures on certain food categories are zero, for which the log is undefined. We use the inverse hyperbolic sine transformation prior to taking the log (MacKinnon and Magee, 1990).

particular, we examine the effect of the intervention on the labor income of the target mother, her husband, and total per capita household income. Summary statistics by round are presented graphically in Figure 7, and regression results are presented in Table 9.

The regression results in Table 9 show per capita household income and paternal income were statistically significantly higher ($p<.1$) among SQ-LNS households, while SQ-LNS had no effect on the income of target mothers.[37,38] These effects are robust to controlling for round of data collection (columns 2 and 8) and instrumenting for timing of enumeration (columns 3 and 9). Based on estimates in columns 1 and 7 which control for the timing of enumeration relative to the birth of the target infant, and noting that the dependent variable is the log of income,[39] taking the exponential of the coefficient on the treatment variable gives the effect as a percentage change. Specifically, per capita household income was, on average, 5% higher in SQ-LNS households, and among households in which the target mother had a husband, his income was 7.3% higher. Using income estimates from the first round as a benchmark, the percent increases imply per capita daily household income was $0.10 higher in SQ-LNS households and paternal daily income was $0.33 higher. The husbands in the sample were primarily drivers, self-employed carpenters or masons, shop owners, and mechanics. Other household members were predominantly petty traders. Each of these jobs is conceivably flexible in terms of time spent working, and the most likely source of higher income working in these jobs is an increase in labor supply.

As with the expenditure data, we also explore heterogeneity in the effect of SQ-LNS on income by months from the birth of the target infant. The results, presented in Table 10, show that the effect of SQ-LNS on each of the income variables did not vary significantly by months from the birth of the target infant.

5.3 Spillover Effect on Sibling Nutritional Status

[37] This set of results is sensitive to controlling for enumerator. Without controlling for enumerator effects, the effect on household income is not statistically significant at conventional levels ($p = .109$), nor is the effect on paternal income ($p =.156$).

[38] Note that the results in Table 9 are based on the full sample of households who took part in the randomized trial. If we limit the sample to households for whom expenditure data were collected (recall that this was a random subsample), the results, shown in Table A4 in the appendix, also show a positive and statistically significant effect on household income, though the effect on paternal income is not significant at conventional levels ($p = .12$).

[39] To deal with incomes of zero, for which the log is undefined, we use the inverse hyperbolic sine transformation, $\ln(yi+(yi^2+1)^{1/2})$, where yi is income (MacKinnon and Magee, 1990).

We have shown that food expenditures, and in particular expenditures on nutrient-dense foods, were higher in households in which the target mother and infant were provided with SQ-LNS relative to those in which the target mother received multiple micronutrient or iron-folic acid tablets. Estimates of the effect of the targeted intervention on expenditures for the subsample of households with a sibling under age five at maternal enrollment, shown in Table A5 of the appendix, show a similar pattern of effects, though they are not as precisely estimated given the smaller sample size.

We now explore whether these observed changes in household behavior generated intrahousehold spillover effects on the nutritional status of the youngest sibling under age five in the household. Average height-for-age z-scores (HAZ), weight-for-age z-scores (WAZ), and BMI-for-age z-scores (BMIZ) are presented by round of data collection in Figure 8. On average, the BMIZ of siblings in SQ-LNS households was statistically significantly lower ($p<.1$) at the third round, but there are otherwise no statistically significant differences in the averages of these indicators of nutritional status between siblings in SQ-LNS and non-SQ-LNS households.

The regression results presented in Table 11 show no spillover effects of the targeted intervention on the nutritional status of siblings and also confirm the estimated effects are not sensitive to controlling for timing of sibling measurement relative to the birth of the target infant and can therefore be used directly. To estimate the effects of the intervention on sibling growth rates over the course of the intervention, we therefore interact a quadratic in the timing of sibling measurement with the treatment indicator. These results, presented in Table 12, show no difference in sibling growth rates between the SQ-LNS and non-SQ-LNS groups.

We also explore potential sources of heterogeneity in the effect of SQ-LNS on sibling growth rates by three factors: sibling age, sibling gender, and maternal height. In early childhood, growth is nonlinear in age (Cheung, 2013), and given that the siblings ranged in age from 11-59 months at maternal enrollment into the trial, spillover effects of the intervention may have been more or less pronounced depending on the child's age. If intrahousehold resource allocation among children favors one gender over the other, sibling gender also represents a potential source of heterogeneity in the spillover effect. Finally, several studies have shown an improvement in catch-up growth among children with taller mothers. Adair

(1999), for example, showed that stunted Filipino children with taller mothers exhibited stronger 'catch-up growth', or an acceleration in growth that moves a child closer to his/her growth potential after a period of deceleration, from ages 2-12 years than children with mothers of shorter stature. Crookston et al. (2010) also found maternal height to be a positive and significant predictor of catch-up growth at age 4.5-6 years among Peruvian children who were stunted in early childhood. These studies suggest the potential for a differential response in linear growth to improved nutrition by maternal height. Age, gender, and baseline z-scores were pre-specified as potential sources of heterogeneity in a statistical analysis plan.[40] Because baseline z-scores were not available for many siblings, they were replaced with maternal height after the analysis plan was posted online but before the analysis was conducted.

Regression results for heterogeneity by sibling age, gender, and maternal height are shown in Tables 13-15. We find no statistically significant heterogeneity in sibling anthropometric status by age or gender. However, the regression results reported in Table 15 show a positive and significant ($p<.1$) coefficient on the interaction between the treatment indicator and maternal height, indicating the targeted provision of maternal and infant SQ-LNS had a positive effect on the length-for-age z-score of siblings with relatively taller mothers. Figure 9 demonstrates the relationship graphically and shows that the average effect of SQ-LNS on HAZ is positive and statistically significant for siblings with mothers approximately 164 cm (~5'4'') and taller.

At first measurement, the average HAZ of siblings with mothers who were 164 cm or taller was -0.8, which was statistically significantly higher ($p<.01$) than the average HAZ of -1.5 among siblings with mothers who were shorter than 164 cm. Given this, the heterogeneity in the spillover effect on sibling HAZ by maternal height has several possible interpretations. One interpretation is that, given their growth potential and relatively better initial HAZs, siblings with taller mothers were more responsive to an increase in consumption of nutrient dense foods. This interpretation echoes Adair (1999) who found that among a population who was experiencing improvements in socioeconomic conditions including rising incomes and increased access to services like electricity and piped water, stunted children with taller mothers and

[40] The statistical analysis plan is available at: http://ilins.org/ilins-project-research/data-analysis.

those who were less severely stunted at baseline were more likely to exhibit catch-up growth. Another interpretation is that maternal height is a proxy for socioeconomic status, and better-off households, who were presumably less resource-constrained, had greater latitude to respond to the targeted intervention with higher food expenditures. Results reported in Table 16 show no heterogeneity in the treatment effect on food and nutrient-dense food expenditures by maternal height for the full sample. However, columns 3-4 of this table show that for the subset of households with a sibling under age five, the effect of SQ-LNS on household expenditures on food and nutrient-dense foods was larger for households with taller target mothers.

6. Possible Drivers of Household Behavioral Responses

We have demonstrated higher household expenditures on both food and non-food items coupled with higher income in households in which the mother and her infant received SQ-LNS. We return to our hypotheses of the mechanisms driving these behavioral responses and speculate on their likelihood, although the extent to which we can empirically rule them out is limited by data availability.

The first hypothesized mechanism is an income effect either through the sales of SQ-LNS or the transfer of calories, both of which are unlikely in the context of this targeted intervention. Anecdotal evidence suggests households were not selling SQ-LNS, and further, converting SQ-LNS to cash would have required substantial demand for the products. Given the complete novelty of SQ-LNS, it is unlikely private demand could have sustained the increased expenditures. An income effect generated via the transfer of calories is also unlikely because the quantity of extra calories per day (118 kcal) was a very small percentage of a typical household's total caloric needs. Assume, for example, a four-member household composed of one pregnant adult female, one adult male, one child under age five, and one child between 5-9 years old. Average daily caloric needs of this household would be approximately 7885 kcal (UNHCR et al., 2004). The additional 118 calories per day would offset approximately 1.5% of this household's total caloric needs, so any income effect would have been quite small.

The second potential mechanism is a freeing up of the household's time constraint due to improvements in the health of mothers and infants consuming SQ-LNS that may have allowed for additional time spent working. The most common jobs reported in our sample – petty traders, drivers, artisans, shop owners, etc. – are, by and large, jobs that allow for flexibility in the time devoted to the job, so if SQ-LNS relaxed a household's time constraint, it is conceivable that extra time could have been used working. Data on maternal and infant morbidity were also collected as part of the trial but have not yet been analyzed, and although the results of the analysis of those data will either lend credibility to or contradict this hypothesis, time-use data would be necessary to legitimately test it.

The final hypothesis is that the way in which SQ-LNS was consumed relative to tablets had a priming effect on mothers. Experimental studies of the effect of priming on health behavior have found, for example, that priming can induce people to be more active (choose the stairs over an elevator) simply by being exposed to scrambled words related to being active (Wryobeck and Chen, 2003), or that priming people with the smell of a cleaning product induces them to keep their eating environment cleaner (Holland et al., 2005). In this intervention, the act of fortifying food with SQ-LNS every day may have had a priming effect that increased mothers' sensitivity to food in general and/or increased the salience of the messages they received about the importance of consuming healthy foods. This heightened sensitivity may have influenced mothers' decision-making surrounding food and motivated an increase in food consumption. Since we found no effect of SQ-LNS on the income of target mothers, the plausibility of this hypothesis rests on mothers' ability to spur changes in the labor supply of other household members in order to fund higher expenditures on food. Women who may have been in a good position in the household to spur such changes include more educated women, older women, and heads of household, all potential indicators of bargaining power within the household. Regressions of heterogeneity in the effect on household and paternal income show no difference in the effect by these maternal characteristics.

7. Limitations

Before discussing the implications of this collection of results, we consider limitations of the work. Our study population is not a random sample of women in this area of Ghana, and certainly not of Ghana as a whole. Each woman in the study was actively seeking timely, formal prenatal care, and the characteristics and preferences of this sample of women, as well as the constraints they faced, were potentially different from women who do not seek out prenatal care. Similarly, households in the sample were, on average, food secure, and it is not clear whether this type of targeted intervention might elicit similar behavioral responses in less food secure settings.

Another consideration relates to the fact that the estimated effects of SQ-LNS on household behavior and sibling nutritional status were generated in the context of a randomized controlled trial in which SQ-LNS were delivered free of charge to households on a weekly or bi-weekly basis. In a more realistic distribution system, SQ-LNS would likely have higher time and, perhaps, financial costs that would be borne by the household (Lybbert, 2011). Depending on the specific mechanisms behind the observed behavioral responses, the way households responded to the intervention in the context of the randomized trial may not carry over when private costs of consuming SQ-LNS are higher. Related, the setting of randomized trial, which was a busy commercial corridor with many self-employed people who, presumably, had the flexibility to work more, may have allowed households to respond to the intervention on margins that would not have been possible in settings in which the supply of labor was less flexible.

A final limitation of the study is that we are unable to address the intrahousehold distribution of food. While our results showed an increase in nutrient-dense food expenditures, our data do not allow for an assessment of how the food was distributed within the household and thus we cannot determine the extent to which this behavioral response influenced the well-being of specific household.

8. Conclusions

Taken together, the results presented in this study are striking: the provision of targeted maternal and infant SQ-LNS induced a labor response, particularly among fathers, that increased household income. Households also increased their expenditures on food, including some nutrient-dense foods, and non-food goods and services. The effect on food expenditures peaked a few months after the birth of the target infant and attenuated as the infant got older. And while on average the targeted intervention did not generate spillover effects on the nutritional status of non-targeted siblings in the household, we found evidence of improvements in the linear growth of children with mothers of relatively tall stature. In what follows, we discuss the relevance of these findings and distill potential policy implications.

Like many developing countries, Ghana is undergoing a nutrition transition in which food consumption patterns are changing to include more processed carbohydrates, sugars, and fats while levels of physical activity are simultaneously declining (Abrahams et al., 2011). The result is the ‘double burden of malnutrition’, characterized by increasing rates of overweight, obesity, and other diet-related chronic diseases coexisting with still relatively high levels of stunting and micronutrient deficiencies (Black et al., 2013). In this context, it is essential to encourage healthy dietary choices – choices to help prevent both undernutrition and overnutrition – in order to stem the myriad private and social costs associated with the double burden.

SQ-LNS is one tool available to help prevent undernutrition in mothers and young children, and if its consumption by these specific household members also brings about desirable changes in household food consumption patterns, the ‘value’ of SQ-LNS may be much higher than what would be suggested based on maternal and child outcomes alone. Households in our sample did increase expenditures on foods like starchy staples and sweets that would be considered undesirable from a nutritional perspective, but households also spent more on nutrient-dense foods like poultry and eggs, fish, milk, and vegetables. Given that the nutrition education provided by the intervention was very low intensity and that the limited information that was provided was identical across the treatment groups, these results suggest that something about preparing and consuming food with SQ-LNS every day – perhaps a physical effect or a psychological one – created circumstances in which households were willing to trade labor for additional consumption. If more could be learned about the specific mechanisms that were at work in driving these behavioral responses, policy makers might be able to leverage them in designing tools to promote healthy diets.

More broadly, the findings in this study point to the value in collecting supplementary data alongside targeted interventions to assess behavioral responses and spillover effects. For targeted nutrition interventions, collecting food consumption and anthropometric data on all household members would provide a detailed look into intrahousehold food allocation and the effect on the nutritional status of all household members. Ex ante identification of relevant behavioral response variables is less obvious, but data on expenditures, income, and time use are all likely candidates, and economic theory and previous findings can be called upon to expand the list based on the specific intervention. Armed with a deeper understanding of how a targeted nutrition intervention plays out within the household, researchers can provide policy makers with a more comprehensive assessment of its associated costs and benefits.

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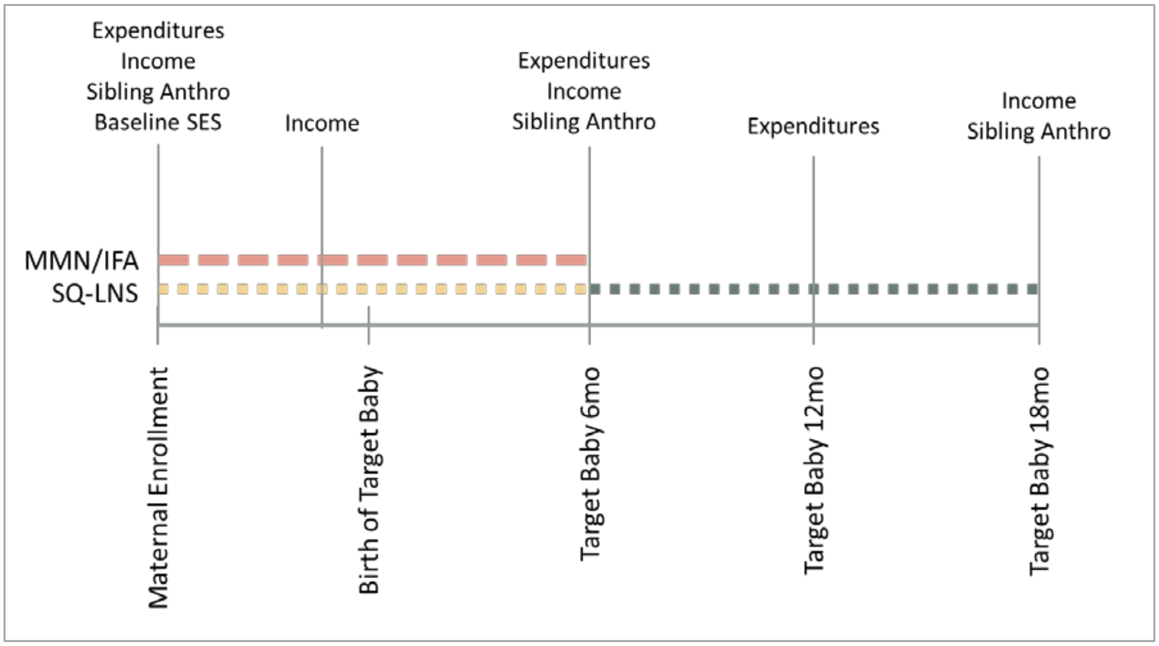

Figure 1. Timeline of Data Collection

Notes: SQ-LNS refers to households in which the mother-infant pair received SQ-LNS. MMN/IFA refers to households in which the mother received multiple micronutrient tablets/iron-folic acid tablets.

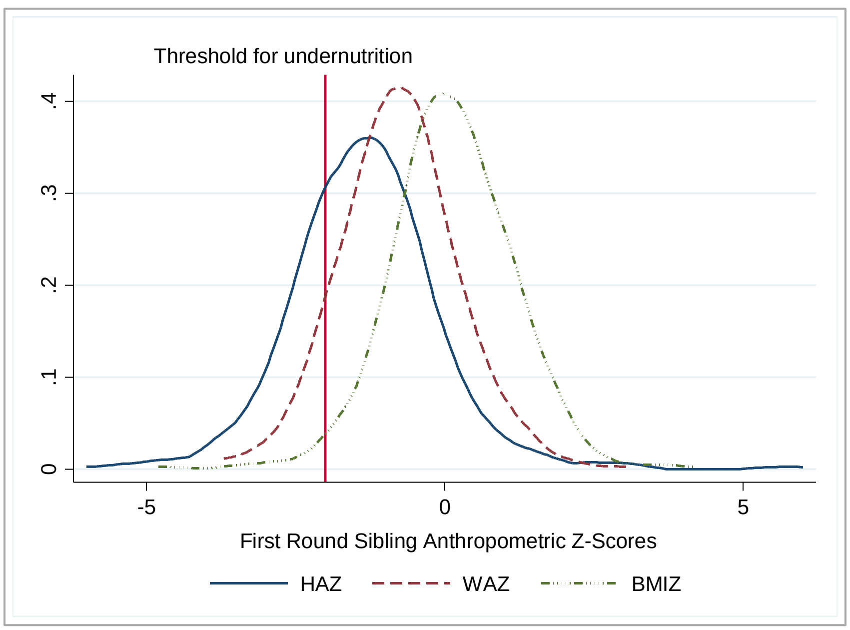

Figure 2. First-Round Sibling Anthropometric Z-Scores

Notes: The vertical line at -2 standard deviations indicates the cut-off for categorizing a child as undernourished based on stunting (low HAZ), underweight (low WAZ), or wasting/thinness (low BMIZ).

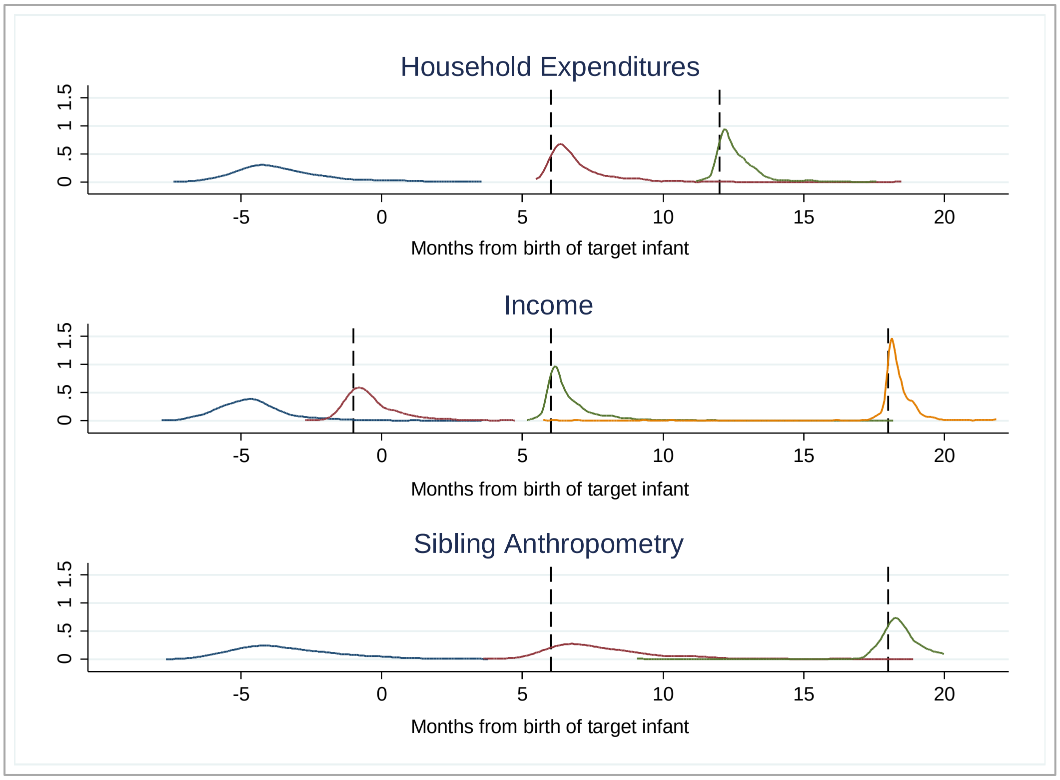

Figure 3. Density of Timing of Enumeration by Round

Notes: Dashed vertical lines show the planned timing of follow-up rounds relative to the birth of the target infant, where the birth of the infant is represented at time equal to zero. The timing of the planned baseline round naturally varied relative to the birth of the targeted infant based on maternal gestational age at enrollment and gestational age at delivery.

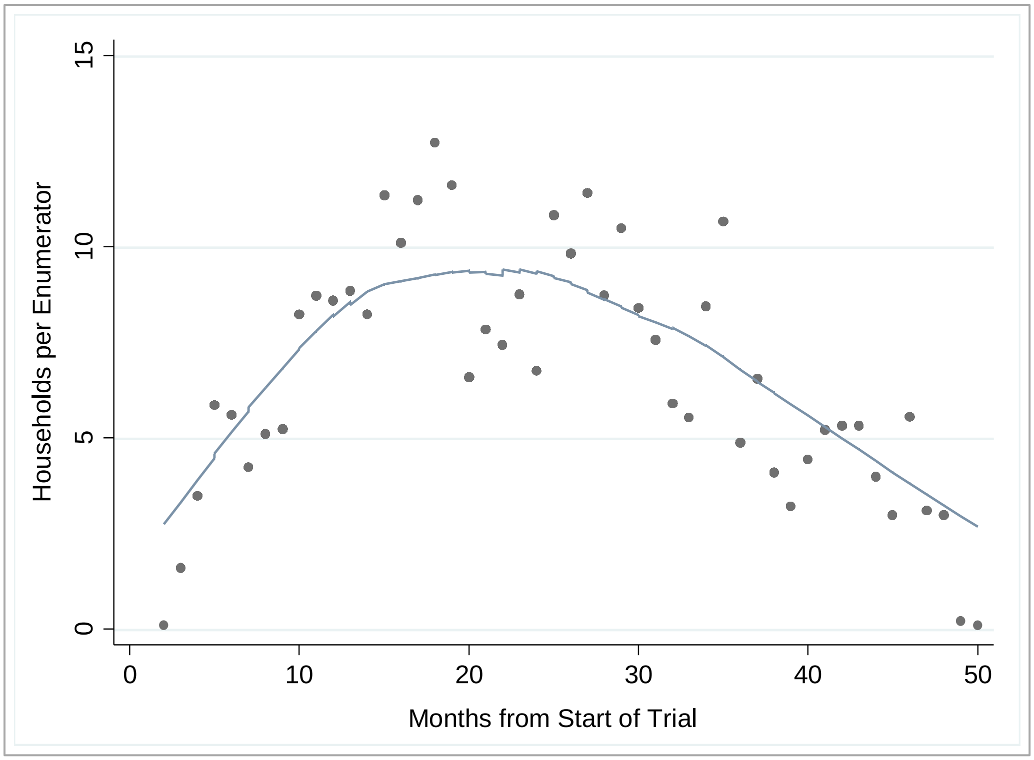

Figure 4. Scatterplot and Smoothed Curve of Number of Households per Enumerator at Each Month During the Trial

Notes: Line fit using locally weighted regression.

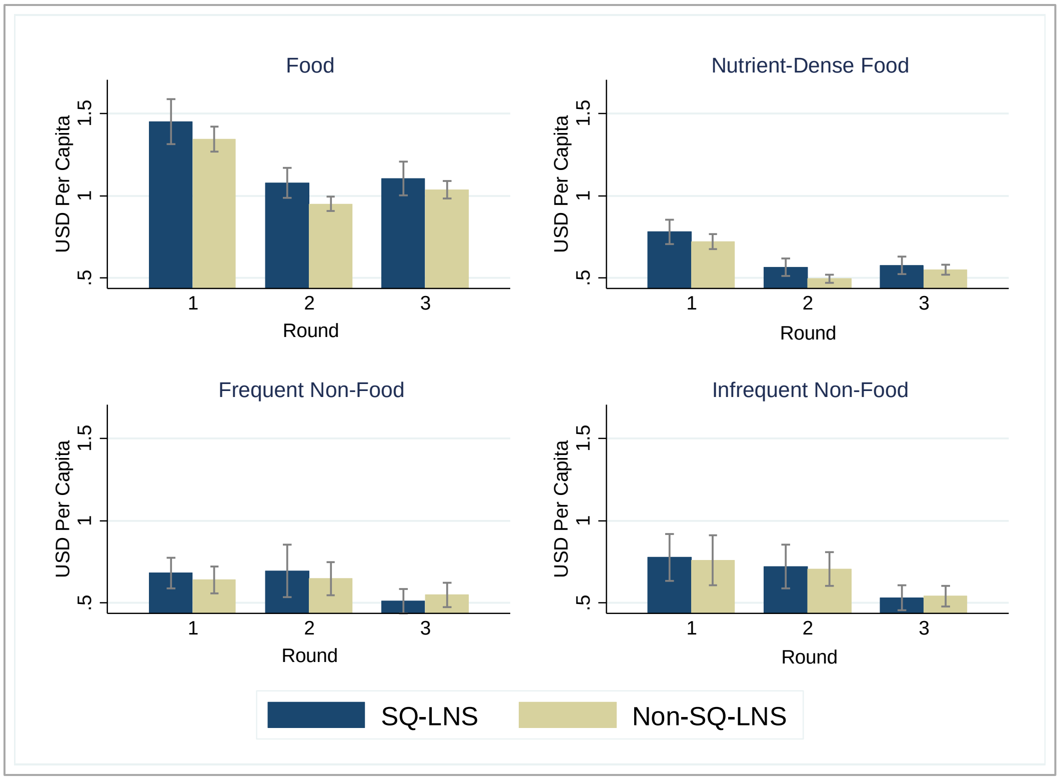

Figure 5. Average Per Capita Daily Household Expenditures (2011 USD) by Treatment Group and Round of Data Collection with 95% Confidence Intervals

Notes: Expenditure data were scheduled to be collected at randomization, six months after the birth of the target infant, and 12 months after birth. Actual first round collection occurred from 0-9 weeks after randomization, and second and third rounds occurred at 5-12mo after birth and 7-after birth, respectively. Nutrient dense foods include animal-source foods, fruits, vegetables, pulses, and nuts. Infrequent non-food expenditures are omitted from the first round because the reference period was the previous 12 months.

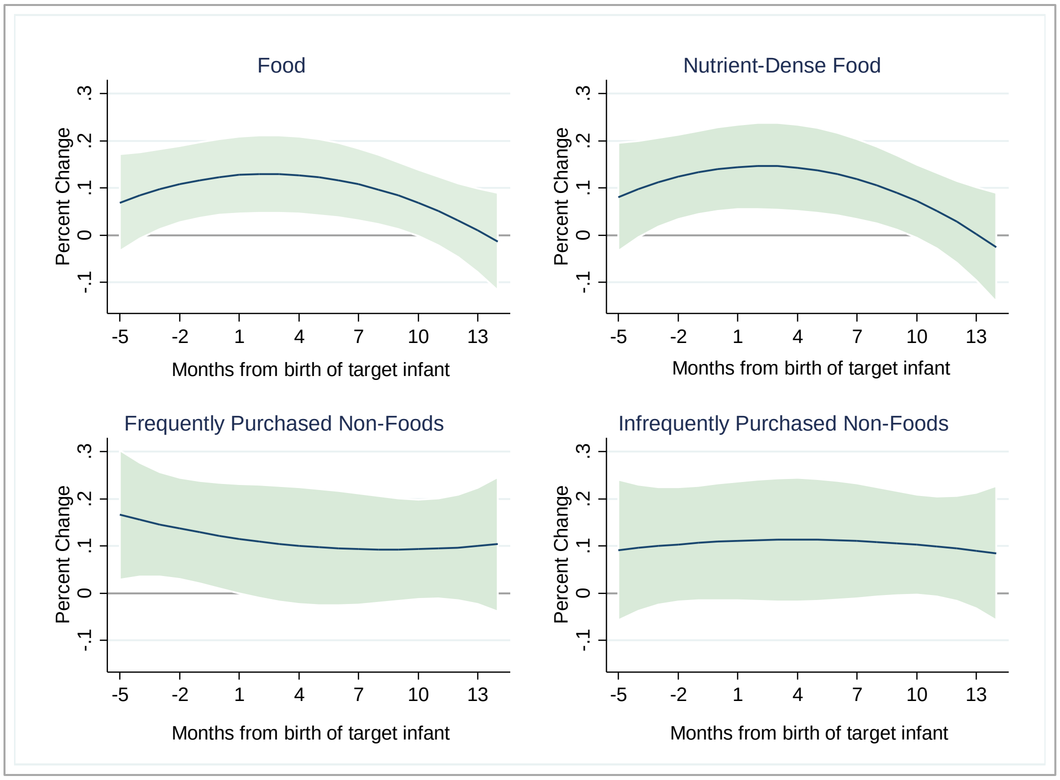

Figure 6. Effect of SQ-LNS on Expenditures Over Time with 95% Confidence Interval

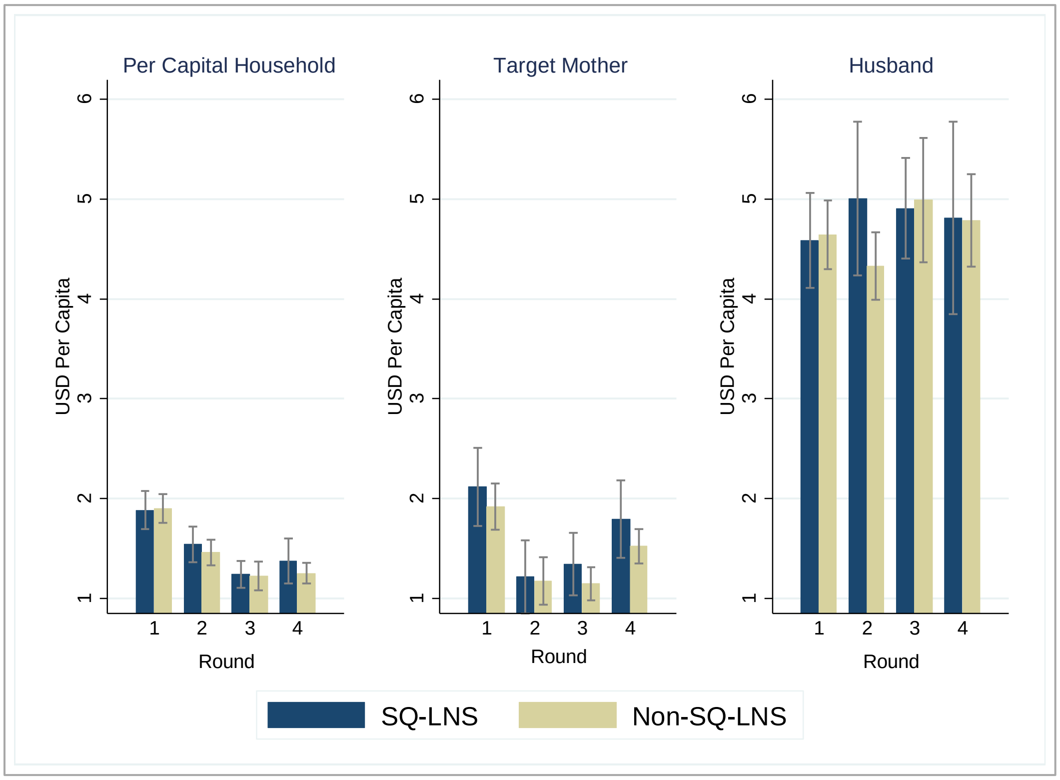

Figure 7. Average Daily Income (2011 USD) by Round and Treatment Group

Notes: Income data were scheduled to be collected at randomization, approx. the 35th week of the target mother's pregnancy, 6 months after the birth of the target infant, and 18 months after birth. Actual first round data collection occurred from 0-29 weeks after randomization, while the second, third, and fourth rounds occurred at 3 months before birth to 3 months after birth, 5-12 months after the birth of the target infant, and 6-22 months after birth, respectively.

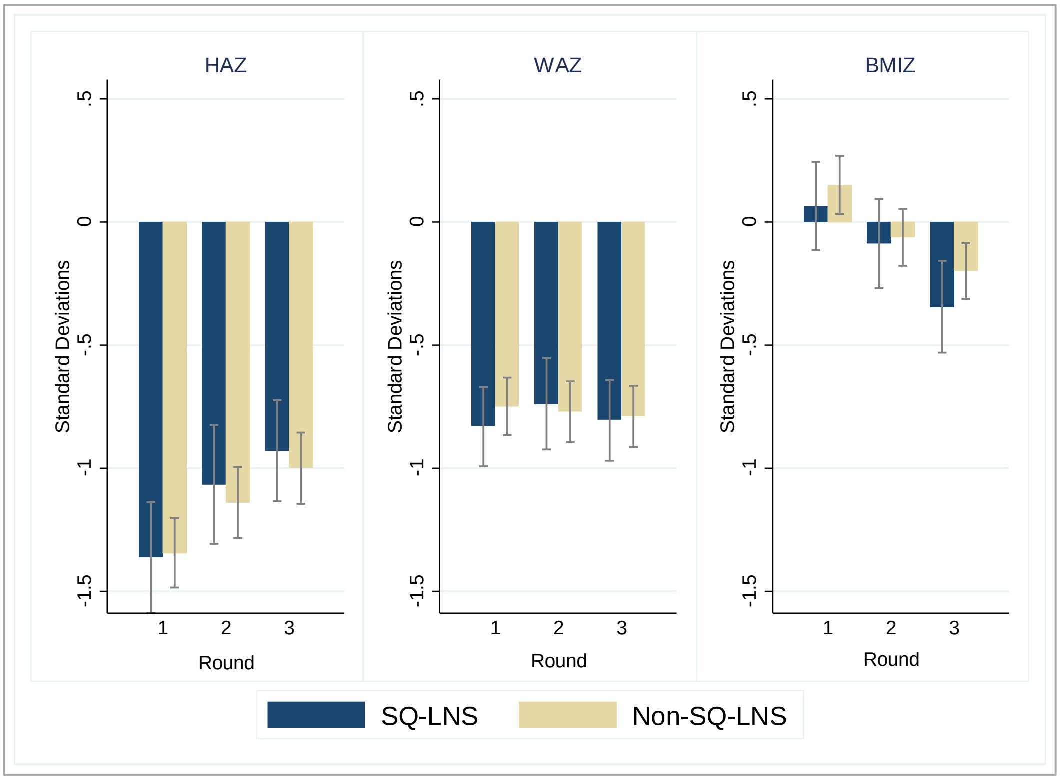

Figure 8. Average Sibling Anthropometric Z-Scores by Round and Treatment Group

Notes: Sibling measurements were scheduled to be collected at randomization and then again at six and 18 months after the birth of the target infant. For the first round, actual collection occurred from the week before randomization to 3.7 months after the birth of the target infant. The second and third rounds were collected from 4-19mo after birth and 9-23mo after birth, respectively.

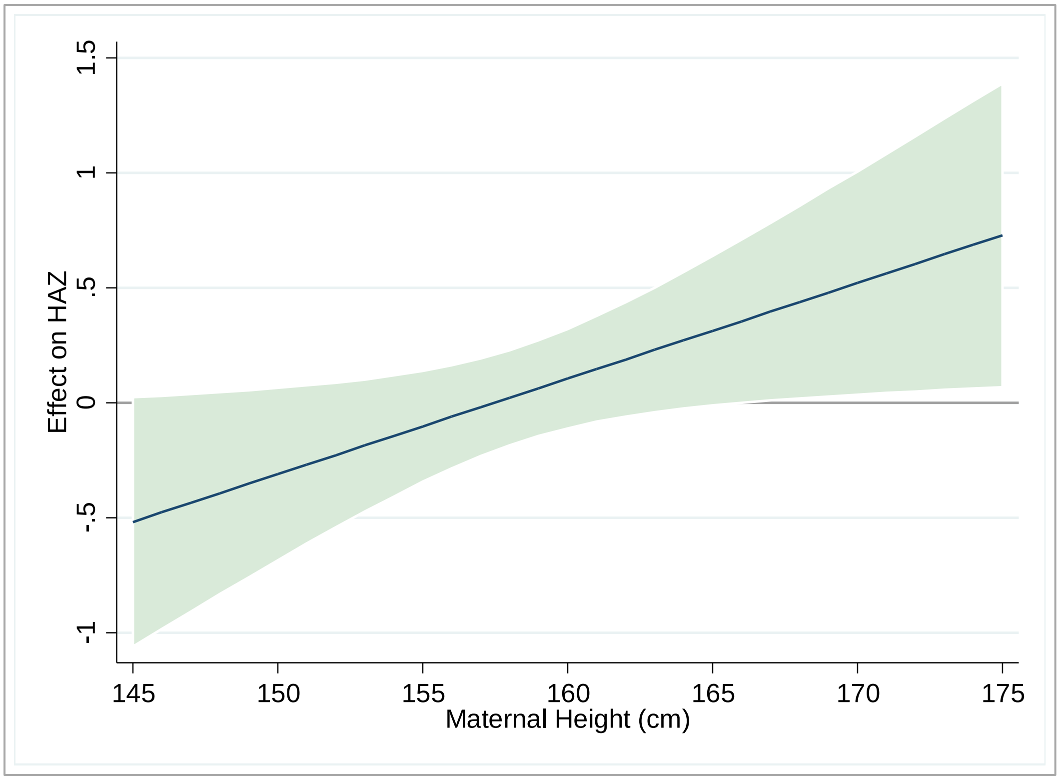

Figure 9. Effect of SQ-LNS on Sibling HAZ by Maternal Height with 95% Confidence Interval

Table 1. First Round Maternal, Household, and Sibling Characteristics

	Variable	Definition	N	Mean	Std Dev	Min, Max
Maternal	Age[b]	Age in years	1270	26.7	5.5	18, 45
	Education[b]	Years of education	1270	7.4	3.7	0, 16
	Head of Household	= 1 if mother is head of her household	1269	0.1	0.3	0, 1
	Children	Number of children who are household members	1270	1.0	1.1	0, 7
	Maternal Daily Income	Income per day in 2011 USD	1270	2.0	3.7	0, 46.8
	Height[b]	Height in centimeters	1270	158.8	5.7	143.4, 177.8
	BMI[b]	Body mass index at enrollment	1270	24.8	4.6	16.2, 61.9
Household	Household Size	Number of household members	1270	4.0	2.1	1, 16
	Children Under 5	Number of children under age 5	1270	0.5	0.6	0, 3
	Female Headed	= 1 if household head is female	1266	0.3	0.4	0, 1
	Asset Index	Proxy measure of socioeconomic status based on asset ownership	1269	0.0	1.0	-2.6, 1.4
	HFIA Score	Household Food Insecurity Access Score	1264	2.6	4.3	0, 22
	PC Food Expenditures	Per capita daily expenditures on food in 2011 USD	676	1.38	0.9	0.04, 7.9
	PC Expenditures on Nutrient-Dense Foods	Per capita daily expenditures on nutrient-dense foods in 2011 USD	693	0.74	0.5	0.01, 5.1
	PC Frequent Non-Food Expenditures	Per capita daily expenditures on frequently purchased non-food items in 2011 USD	682	0.65	0.84	0.03, 11.2
	PC Infrequent Non-Food Expenditures	Per capita daily expenditures on infrequently purchased non-food items in 2011 USD	655	0.76	1.46	0.02, 26.1
	Paternal Daily Income	Daily income of husband of target mother (2011 USD)	841	4.6	4.1	0, 35.0
	PC Household Daily Income	Per capita household income per day in 2011 USD	1237	1.9	2.1	0, 18.0
Sibling	Age[b]	Age in months at maternal enrollment into trial	410	35.5	11.8	9.7, 59.6
	Female[b]	= 1 if sibling is female	410	0.50	0.5	0, 1
	HAZ	Height-for-age z-score	407	-1.35	1.2	-6.1, 5.8
	WAZ	Weight-for-age z-score	410	-0.78	1.0	-3.7, 3.1
	BMIZ	BMI-for-age z-score	404	0.12	1.0	-4.8, 4.2

[b] Variable reflects true baseline.

Notes: A household member is defined as anyone who has been regularly sleeping in the household's dwelling and sharing food from the same cooking pots for at least the last three months. Nutrient dense foods include animal-source foods, fruits, vegetables, pulses, and nuts.

Table 2. First Round Characteristics by Treatment Group

	Variable	SQ-LNS N	SQ-LNS Mean (std error)	Non-SQ-LNS N	Non-SQ-LNS Mean (std error)
Maternal	Age[b]	424	26.9 (.27)	846	26.6 (.19)
	Education[b]	424	7.3 (.19)	846	7.5 (.12)
	Head of Household	424	.14 (.02)	846	.14 (.01)
	Number of Children	424	.94 (.05)	846	.97 (.04)
	Maternal Daily Income	424	2.1 (.20)	846	1.9 (.12)
	Height[b]	424	158.9 (.26)	846	158.8 (.20)
	BMI[b]	424	25.1 (.22)	846	24.7 (.16)
Household	Household Size	424	3.9 (.10)	846	4.0 (.07)
	Children Under 5	424	.50 (.03)	846	.50 (.02)
	Female Headed	424	.27 (.02)	842	.28 (.02)
	Asset Index	424	-.07 (.05)	845	.02 (.03)
	HFIA Score	423	2.53 (.20)	841	2.65 (.15)
	PC Food Expenditures	215	1.45 (.07)	461	1.35 (.04)
	PC Expenditures on Nutrient-Dense Foods	224	.78 (.04)	469	.72 (.02)
	PC Non-Food Frequent Expenditures	218	.68 (.05)	464	.64 (.04)
	PC Non-Food Infrequent Expenditures	214	.78 (.07)	441	.76 (.08)
	Paternal Daily Income	283	4.6 (.24)	558	4.7 (.18)
	PC Household Daily Income	417	1.9 (.10)	820	1.9 (.07)
Sibling	Age[b]	135	35.3 (1.0)	275	35.6 (.70)
	Female[b]	135	.48 (.04)	275	.51 (.03)
	HAZ	131	-1.36 (.11)	276	-1.3 (.07)
	WAZ	135	-.83 (.08)	275	-.75 (.06)
	BMIZ	130	.07 (.09)	274	.15 (.06)

Significance codes for difference in means between LNS and non-LNS groups: *** ($p < .01$), ** ($p < .05$), * ($p < .1$).

[b] Variable reflects true baseline.

Notes: SQ-LNS indicates the target mother and infant were randomized to receive SQ-LNS and non-SQ-LNS indicates the mother received either multiple micronutrient or iron-folic acid tablets. Nutrient dense foods include animal-source foods, fruits, vegetables, pulses, and nuts.

Table 3. Rates of Attrition by Treatment Group

Survey		N	Round 1	Round 2	Round 3	Round 4
Income	SQ-LNS	424	0%	8.0%	16.5%	21.2%
	Non-SQ-LNS	851	0.6%	9.1%	18.9%	22.1%
Household Expenditures	SQ-LNS	235	2.6%	14.0%	23.0%	
	Non-SQ-LNS	485	2.3%	20.8%	27.0%	
Sibling Anthropometry	SQ-LNS	137	6%	24.5%	28.7%	
	Non-SQ-LNS	278	3.8%	23.9%	29.8%	

Table 4. Kolmogorov-Smirnov Test of Equality of Distributions

Round 1 Variable	P-Value at Round 2	P-Value at Round 3	P-Value at Round 4
ln(Maternal Income)	.56	.99	.70
ln(Paternal Income)	.82	.79	.93
ln(PC Household Income)	.10	.20	.39
ln(PC Food Expenditures)	.40	.65	
ln(PC Nutrient-Dense Expenditures)	.26	.31	
ln(PC Frequent Non-Food Expenditures)	.16	.73	
ln(PC Infrequent Term Non-Food Expenditures)	.60	.83	
HAZ	.69	.54	
WAZ	.87	.65	
BMIZ	.64	.43	

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

Table 5. Effect of SQ-LNS on Per Capita Daily Household Expenditures

	Food			Nutrient-Dense Food			Frequent Non-Food			Infrequent Non-Food		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
SQ-LNS	0.072**	0.074**	0.074**	0.080**	0.081**	0.082**	0.119**	0.118**	0.117*	0.102**	0.100**	0.102**
	(0.034)	(0.034)	(0.033)	(0.038)	(0.038)	(0.038)	(0.048)	(0.048)	(0.062)	(0.051)	(0.051)	(0.046)
Constant	0.068	0.128	0.054	-0.763	-0.684	-0.777	-1.935***	-1.901***	-1.933**	-1.496**	-1.466**	-1.486*
	(0.470)	(0.469)	(0.547)	(0.522)	(0.521)	(0.569)	(0.668)	(0.668)	(0.821)	(0.734)	(0.734)	(0.841)
Control for Months	YES	NO	YES	YES	NO	YES	YES	NO	YES	YES	NO	YES
Controls for Round	NO	YES	NO	NO	YES	NO	NO	YES	NO	NO	YES	NO
IV for Months	NO	NO	YES	NO	NO	YES	NO	NO	YES	NO	NO	YES
N	1766	1766	1766	1805	1805	1805	1780	1780	1780	1730	1730	1730
Wald Chi^2	292.2	340.2		252.3	299.9		484.4	482.1		610.8	629.5	
Prob > Chi^2	0.000	0.000		0.000	0.000		0.000	0.000		0.000	0.000	
Kleibergen-Paap F-Stat			22.6			19.9			21.0			21.6
Overall R^2			0.152			0.112			0.304			0.324

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

Notes: Dependent variables are log of: per capita total daily food expenditures for (1)-(3), per capita daily expenditures on nutrient-dense food for (4)-(6), per capita daily expenditures on frequently purchased non-food items for (7)-(9), and per capita daily expenditures on infrequently purchased non-food items for (10)-(12). Nutrient dense foods include animal-source foods, fruits, vegetables, pulses, and nuts. Controls for enumerator, season and year of maternal enrollment into the trial, language primarily spoken at home, and maternal gestational age at enrollment, height, and education are included in each model (unreported). 'Control for Months' indicates a control for the timing of enumeration measured as the number of months from the birth of the target infant was included. 'Controls for Round' indicates a set of controls for round of data collection were included. 'IV for Months' indicates 2SLS was used to instrument for months from the birth of the target infant with the instrument 'households per enumerator'. Cluster-robust standard errors in parentheses. Cluster-robust standard errors are bootstrapped for IV regressions.

Table 6. Effect of SQ-LNS on Nutrient-Dense Food Category Daily Expenditures

	(1) Meat	(2) Poultry and Eggs	(3) Fish	(4) Milk	(5) Fruit	(6) Vegetables	(7) Pulses and Nuts
SQ-LNS	0.004	0.008*	0.020***	0.007**	0.005	0.012**	0.002
	(0.004)	(0.004)	(0.007)	(0.003)	(0.004)	(0.005)	(0.002)
Constant	0.065	0.021	0.275**	0.021	0.049	0.112*	0.072***
	(0.066)	(0.061)	(0.108)	(0.032)	(0.046)	(0.063)	(0.022)
N	1822	1817	1820	1822	1813	1818	1822
Wald Chi^2	137.8	158.8	300.8	179.2	236.0	287.9	254.0
Prob > Chi^2	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Significance codes: *** (p < .01), ** (p < .05), * (p < .1).
Notes: Dependent variables are natural log of the inverse hyperbolic sine, $(yi+(yi^2+1)^{1/2})$, of expenditures in each food category. Controls for enumerator, timing of enumeration relative to birth of target infant, season and year of maternal enrollment into the trial, language primarily spoken at home, and maternal gestational age at enrollment, height, and education are included in the model (unreported). Cluster-robust standard errors in parentheses.

Table 7. Effect of SQ-LNS on Other Food Category Daily Expenditures

	(1) Cereals	(2) Oils and Fats	(3) Starchy Staples	(4) Spices	(5) Sugar and Sweets	(6) Beverages	(7) Street Food
SQ-LNS	0.019***	0.003	0.011**	0.003**	0.004**	0.006	-0.003
	(0.006)	(0.002)	(0.005)	(0.002)	(0.002)	(0.004)	(0.005)
Constant	0.175**	0.064**	0.220***	0.058**	0.038**	0.062	0.037
	(0.080)	(0.026)	(0.070)	(0.025)	(0.019)	(0.041)	(0.067)
N	1811	1819	1813	1820	1821	1806	1821
Wald Chi^2	170.7	160.3	218.2	335.1	120.6	242.0	134.2
Prob > Chi^2	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Significance codes: *** (p < .01), ** (p < .05), * (p < .1).
Notes: Dependent variables are log of the inverse hyperbolic sine, $(yi+(yi^2+1)^{1/2})$, of expenditures in each food category. Controls for enumerator, timing of enumeration relative to birth of target infant, season and year of maternal enrollment into the trial, language primarily spoken at home, and maternal gestational age at enrollment, height, and education are included in the model (unreported). Cluster-robust standard errors in parentheses.

Table 8. Timing of Effect of SQ-LNS on Per Capita Daily Household Expenditures

	(1) Food	(2) Nutrient-Dense Food	(3) Frequent Non-Food	(4) Infrequent Non-Food
LNS	0.123***	0.140***	0.122**	0.109*
	(0.041)	(0.045)	(0.057)	(0.063)
Months	-0.028***	-0.029***	-0.005	0.002
	(0.003)	(0.004)	(0.004)	(0.005)
LNS X Months	0.005	0.006	-0.007	0.002
	(0.005)	(0.006)	(0.008)	(0.009)
$Months^2$	0.002***	0.002***	-0.000	-0.002***
	(0.000)	(0.000)	(0.000)	(0.001)
LNS X $Months^2$	-0.001*	-0.001*	0.000	-0.000
	(0.001)	(0.001)	(0.001)	(0.001)
Constant	-0.035	-0.856	-1.927***	-1.404*
	(0.468)	(0.521)	(0.671)	(0.738)
N	1766	1805	1780	1730
Wald Chi^2	339.6	299.3	489.5	623.8
Prob > Chi^2	0.000	0.000	0.000	0.000

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

Notes: Dependent variables are log of (1) per capita total daily food expenditures, (2) per capita daily expenditures on nutrient-dense food, (3) per capita daily expenditures on frequently purchased non-food items, and (4) per capita daily expenditures on infrequently purchased non-food items. Nutrient dense foods include animal-source foods, fruits, vegetables, pulses, and nuts. Months indicates the number of months from the birth of the target infant to the date of enumeration. Controls for enumerator, season and year of maternal enrollment into the trial, language primarily spoken at home, and maternal gestational age at enrollment, height, and education are included in the model (unreported). Cluster-robust standard errors in parentheses.

Table 9. Effect of SQ-LNS on Daily Income

	PC Household			Target Mother			Husband		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
SQ-LNS	0.050*	0.051*	0.052*	0.032	0.031	0.034	0.070*	0.070*	0.070*
	(0.029)	(0.029)	(0.030)	(0.041)	(0.041)	(0.045)	(0.043)	(0.043)	(0.039)
Constant	0.680	0.726*	0.653*	1.565***	1.618***	1.511**	1.254**	1.252**	1.253
	(0.414)	(0.414)	(0.395)	(0.570)	(0.569)	(0.635)	(0.575)	(0.575)	(0.787)
Control for Months	YES	NO	YES	YES	NO	YES	YES	NO	YES
Controls for Round	NO	YES	NO	NO	YES	NO	NO	YES	NO
IV for Months	NO	NO	YES	NO	NO	YES	NO	NO	YES
N	3170	3170	3170	3192	3192	3192	2137	2137	2137
Wald Chi^2	334.3	377.6		286.8	320.5		241.3	242.0	
Prob > Chi^2	0.000	0.000		0.000	0.000		0.000	0.000	
Kleibergen-Paap F-Stat			182.4			182.3			108.4
Overall R^2			0.148			0.111			0.138

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

Notes: Dependent variables are log of the inverse hyperbolic sine, $(yi+(yi^2+1)^{1/2})$, of daily: per capita household income for (1)-(3), income of target mother for (4)-(6), and income of target mother's husband for (7)-(9). Controls for enumerator, season and year of maternal enrollment into the trial, language primarily spoken at home, and maternal gestational age at enrollment, height, and education are included in each model (unreported). 'Control for Months' indicates a control for the timing of enumeration measured as the number of months from the birth of the target infant was included. 'Controls for Round' indicates a set of controls for round of data collection were included. 'IV for Months' indicates 2SLS was used to instrument for months from the birth of the target infant with the instrument 'households per enumerator'. Cluster-robust standard errors in parentheses. Cluster-robust standard errors are bootstrapped for IV regressions.

Table10. Timing of the Effect of SQ-LNS on Income

	(1) Per Capita Household	(2) Target Mother	(3) Husband
SQ-LNS	0.056	0.010	0.088*
	(0.037)	(0.048)	(0.052)
Months	-0.029***	-0.009	0.001
	(0.004)	(0.006)	(0.007)
SQ-LNS X Months	0.000	0.008	-0.002
	(0.007)	(0.010)	(0.012)
$Months^2$	0.001***	0.001***	0.000
	(0.000)	(0.000)	(0.000)
SQ-LNS X $Months^2$	-0.000	-0.000	-0.000
	(0.000)	(0.001)	(0.001)
Constant	0.700*	1.594***	1.249**
	(0.413)	(0.570)	(0.576)
N	3170	3192	2137
Wald Chi^2	390.061	314.789	243.657
Prob > Chi^2	0.000	0.000	0.000

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

Notes: Dependent variables are log of the inverse hyperbolic sine, $(yi+(yi^2+1)^{1/2})$, of daily (1) per capita household income, (2) income of target mother, and (3) income of target mother's husband. Controls for enumerator, season and year of maternal enrollment into the trial, language primarily spoken at home, and maternal gestational age at enrollment, height, and education are included in the model (unreported). Cluster-robust standard errors in parentheses.

Table 11. Effect of SQ-LNS on Sibling Anthropometric Z-Scores

	HAZ			WAZ			BMIZ		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
SQ-LNS	0.047	0.049	0.046	-0.031	-0.031	-0.030	-0.099	-0.102	-0.095
	(0.105)	(0.105)	(0.082)	(0.084)	(0.084)	(0.089)	(0.087)	(0.088)	(0.080)
Constant	-14.679***	-14.770***	-14.697***	-8.967***	-8.958***	-8.945***	0.676	0.778	0.735
	(1.505)	(1.503)	(1.453)	(1.174)	(1.175)	(1.018)	(1.212)	(1.213)	(0.772)
Control for Months	YES	NO	YES	YES	NO	YES	YES	NO	YES
Controls for Round	NO	YES	NO	NO	YES	NO	NO	YES	NO
IV for Months	NO	NO	YES	NO	NO	YES	NO	NO	YES
N	1031	1031	1031	1043	1043	1043	1028	1028	1028
Wald Chi^2	373.1	383.4		102.6	103.0		162.1	165.3	
Prob > Chi^2	0.000	0.000		0.000	0.000		0.000	0.000	
Kleibergen-Paap F-Stat			67.7			75.2			72.4
Overall R^2			0.248			0.197			0.109

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

Notes: Dependent variables are sibling height-for-age z-scores (1)-(3), weight-for-age z-scores (4)-(6), and BMI-for-age z-scores (7)-(9). Controls for anthropometrist, sibling age at enrollment, sibling gender, enumerator, season and year of maternal enrollment into the trial, language primarily spoken at home, and maternal gestational age at enrollment, height, and education are included in each model (unreported). 'Control for Months' indicates a control for the timing of enumeration measured as the number of months from the birth of the target infant was included. 'Controls for Round' indicates a set of controls for round of data collection were included. 'IV for Months' indicates 2SLS was used to instrument for months from the birth of the target infant with the instrument 'siblings per enumerator'. Cluster-robust standard errors in parentheses. Cluster-robust standard errors are bootstrapped for IV regressions.

Table 12. Effect of SQ-LNS on Sibling Anthropometric Z-Scores Over Time

	(1) HAZ	(2) WAZ	(3) BMIZ
SQ-LNS	0.063	-0.011	-0.063
	(0.114)	(0.091)	(0.097)
Months	0.013***	0.000	-0.012***
	(0.003)	(0.003)	(0.005)
SQ-LNS X Months	0.003	-0.000	-0.001
	(0.006)	(0.005)	(0.008)
$Months^2$	0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)
SQ-LNS X $Months^2$	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.001)
Constant	-13.944***	-7.926***	1.491
	(1.509)	(1.245)	(1.244)
N	1031	1043	1028
Wald Chi^2	382.8	65.1	133.8
Prob > Chi^2	0.000	0.000	0.000

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

Notes: Dependent variables are sibling height-for-age z-scores (1), weight-for-age z-scores (2), and BMI-for-age z-scores (3). Controls for anthropometrist, sibling age at enrollment, sibling gender, enumerator, season and year of maternal enrollment into the trial, language primarily spoken at home, and maternal gestational age at enrollment, height, and education are included in the model (unreported). Cluster-robust standard errors in parentheses.

Table 13. Heterogeneity in Sibling Spillover Effects by Sibling Age at Maternal Enrollment

	(1) HAZ	(2) WAZ	(3) BMIZ
SQ-LNS	1.115	0.888	0.281
	(1.141)	(0.945)	(0.822)
Months	-0.066**	0.044*	0.130***
	(0.027)	(0.026)	(0.046)
SQ-LNS X Months	0.019	-0.038	-0.081
	(0.056)	(0.045)	(0.080)
Months^2	0.002	-0.001	-0.004
	(0.002)	(0.001)	(0.003)
SQ-LNS X Months^2	-0.004	-0.001	0.003
	(0.004)	(0.003)	(0.005)
Age	-0.055*	-0.010	0.043
	(0.033)	(0.030)	(0.028)
SQ-LNS X Age	-0.054	-0.038	-0.002
	(0.063)	(0.052)	(0.046)
Months X Age	0.004**	-0.002*	-0.007***
	(0.001)	(0.001)	(0.002)
SQ-LNS X Months X Age	-0.001	0.002	0.004
	(0.003)	(0.003)	(0.004)
Months^2 X Age	-0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)
SQ-LNS X Months^2 X Age	0.000	0.000	-0.000
	(0.000)	(0.000)	(0.000)
Age^2	0.001**	0.000	-0.001*
	(0.000)	(0.000)	(0.000)
SQ-LNS X Age^2	0.001	0.000	-0.000
	(0.001)	(0.001)	(0.001)
Months X Age^2	-0.000*	0.000	0.000**
	(0.000)	(0.000)	(0.000)
SQ-LNS X Months X Age^2	0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)
Months^2 X Age^2	0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)
SQ-LNS X Months^2 X Age^2	-0.000	-0.000	0.000
	(0.000)	(0.000)	(0.000)
Constant	-13.105***	-7.927***	0.513
	(1.555)	(1.304)	(1.286)
N	1031	1043	1028
Wald Chi^2	506.8	79.3	281.1
Prob > Chi^2	0.000	0.000	0.000

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

Notes: Dependent variables are sibling height-for-age z-scores (1), weight-for-age z-scores (2), and BMI-for-age z-scores (3). Age indicates sibling age at maternal enrollment in months. Months indicates the number of months from the birth of the target infant to the sibling measurement. Controls for anthropometrist, sibling gender, enumerator, season and year of maternal enrollment into the trial, language primarily spoken at home, and maternal gestational age at enrollment, height, and education are included in the model (unreported). Cluster-robust standard errors in parentheses.

Table 14. Heterogeneity in Sibling Spillover Effects by Sibling Gender

	(1) HAZ	(2) WAZ	(3) BMIZ
SQ-LNS	-0.022	0.033	0.065
	(0.152)	(0.129)	(0.150)
Months	0.019***	0.005	-0.009
	(0.003)	(0.004)	(0.006)
SQ-LNS X Months	-0.000	0.001	-0.000
	(0.009)	(0.007)	(0.012)
$Months^2$	-0.000	-0.000*	-0.000
	(0.000)	(0.000)	(0.000)
SQ-LNS X $Months^2$	0.000	-0.000	-0.000
	(0.001)	(0.000)	(0.001)
Female	0.141	0.183*	0.127
	(0.127)	(0.110)	(0.110)
SQ-LNS X Female	0.167	-0.094	-0.259
	(0.233)	(0.185)	(0.194)
Months X Female	-0.012**	-0.010*	-0.007
	(0.006)	(0.006)	(0.009)
SQ-LNS X Months X Female	0.007	-0.002	-0.002
	(0.013)	(0.010)	(0.017)
$Months^2$ X Female	0.001***	0.001**	0.000
	(0.000)	(0.000)	(0.001)
SQ-LNS X $Months^2$ X Female	-0.000	0.000	0.001
	(0.001)	(0.001)	(0.001)
Constant	-13.878***	-7.963***	1.392
	(1.529)	(1.261)	(1.244)
N	1031	1043	1028
Wald Chi^2 (df)	453.0	76.4	135.8
Prob > Chi^2	0.000	0.000	0.000

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

Notes: Dependent variables are sibling height-for-age z-scores (1), weight-for-age z-scores (2), and BMI-for-age z-scores (3). Months indicates the number of months from the birth of the target infant to the sibling measurement. Controls for anthropometrist, sibling age at enrollment, enumerator, season and year of maternal enrollment into the trial, language primarily spoken at home, and maternal gestational age at enrollment, height, and education are included in the model (unreported). Cluster-robust standard errors in parentheses.

Table 15. Heterogeneity in Sibling Spillover Effect on HAZ by Maternal Height

	(1) HAZ
SQ-LNS	-5.466
	(3.345)
Months	0.207***
	(0.079)
SQ-LNS X Months	-0.328
	(0.201)
Months^2	-0.008**
	(0.004)
SQ-LNS X Months^2	0.025**
	(0.010)
Height	0.071***
	(0.012)
SQ-LNS X Height	0.035*
	(0.021)
Months X Height	-0.001**
	(0.000)
SQ-LNS X Months X Height	0.002*
	(0.001)
Months^2 X Height	0.000**
	(0.000)
SQ-LNS X Months^2 X Height	-0.000**
	(0.000)
Constant	-12.834***
	(1.930)
N	1031
Wald Chi^2 (df)	415.5
Prob > Chi^2	0.000

Significance codes: *** (p < .01), ** (p < .05), * (p < .1).
Notes: Dependent variable is sibling height-for-age z-score. Months indicates the number of months from the birth of the target infant to the sibling measurement. Controls for anthropometrist, sibling age at enrollment, sibling gender, enumerator, season and year of maternal enrollment into the trial, language primarily spoken at home, and maternal gestational age at enrollment and education are included in the model (unreported). Cluster-robust standard errors in parentheses.

Table16. Heterogeneity in Effect of SQ-LNS on Food Expenditures by Maternal Height

	Full Sample		Sibling Subsample	
	(1)	(2)	(3)	(4)
	Food	Nutrient-Dense Food	Food	Nutrient-Dense Food
SQ-LNS	-0.818	-0.524	-3.749**	-4.688**
	(0.719)	(0.577)	(1.767)	(1.999)
Height	-0.001	-0.001	-0.005	-0.007
	(0.002)	(0.002)	(0.006)	(0.006)
SQ-LNS X Height	0.006	0.004	0.024**	0.030**
	(0.005)	(0.004)	(0.011)	(0.013)
Constant	1.276***	0.753***	0.861	0.400
	(0.379)	(0.292)	(0.972)	(1.072)
N	1766	1805	621	634
Wald Chi^2	292.6	244.1	158.4	151.5
Prob > Chi^2	0.000	0.000	0.000	0.000

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

Notes: Dependent variables are log of per capita total daily food expenditures for (1) and (3) and log of per capita daily expenditures on nutrient-dense food for (2) and (4). Nutrient dense foods include animal-source foods, fruits, vegetables, pulses, and nuts. Controls for enumerator, season and year of maternal enrollment into the trial, language primarily spoken at home, and maternal gestational age at enrollment, height, and education are included in the model (unreported). Cluster-robust standard errors in parentheses.

Appendix

Table A1. Nutrient Composition of LNS-Child, LNS-P&L, Multiple Micronutrient Tablets, and Iron-Folic Acid Tablets

Nutrient	Nutrient Content per Daily Ration			
	LNS-Child	LNS-P&L	Multiple Micronutrient Tablet	Iron-Folic Acid Tablet
Daily Ration (g/day)	20	20		
Total energy (kcal)	118	118		
Protein (g)	2.6	2.6		
Fat (g)	9.6	10		
Linoleic acid (g)	4.46	4.59		
α-Linoleic acid (g)	0.58	0.59		
Vitamin A (µg RE)	400	800	800	
Vitamin C (mg)	30	100	100	
Vitamin B_1 (mg)	0.3	2.8	2.8	
Vitamin B_2 (mg)	0.4	2.8	2.8	
Niacin (mg)	4	36	36	
Folic acid (mg)	80	400	400	400
Pantothenic acid (mg)	1.8	7	7	
Vitamin B_6 (mg)	0.3	3.8	3.8	
Vitamin B_{12} (µg)	0.5	5.2	5.2	
Vitamin D (IU)	200	400	400	
Vitamin E (mg)	6	20	20	
Vitamin K (µg)	30	45	45	
Iron (mg)	6	20	20	60
Zinc (mg)	8	30	30	
Cu (mg)	0.34	4	4	
Calcium (mg)	280	280		
Phosphorus (mg)	190	190		
Potassium (mg)	200	200		
Magnesium (mg)	40	65		
Selenium (µg)	20	130	130	
Iodine (µg)	90	250	250	
Manganese (mg)	1.2	2.6	2.6	

Sources: Adu-Afarwuah et al. (2014); Adu-Afarwuah et al. (2011)

Table A2. Foods Included in Each Food Expenditure Category

Cereals	**Fruits**	**Spices**
[101] Guinea corn/Sorghum	[701] Coconut	[1101] Salt
[102] Maize/corn dough	[702] Banana	[1102] Maggie, Royco
[103] Millet	[703] Orange/tangerine	[1103] Curry powder
[104] Rice (local and imported)	[704] Pineapple	[1104] Ginger
[105] Bread, buns	[705] Mango	**Sugars and Sweets**
[106] Biscuits	[706] Avocado pear	[1105] Sugar (cube, granulated)
[107] Flour (wheat)	[707] Watermelon	[1106] Honey
[108] Baby food (cerelac, etc)	[708] Pawpaw	[1107] Jam
[109] Other cereal products	[709] Other fruits not canned	[1108] Fanice, FanYogo
Meat	[710] Canned or processed fruits	[1109] Chocolate
[201] Corned beef	**Vegetables**	[1110] Other
[202] Pork	[801] Cocoyam leaves (kontomire)	**Beverages**
[203] Beef	[802] Garden eggs	[1201] Coffee, tea, milo
[204] Goat meat	[803] Okro	[1204] Minerals (fanta, coke, malta)
[205] Mutton	[804] Carrots	[1206] Fruit juices
[206] Bushmeat/wild game	[805] Pepper (fresh or dried)	[1207] Mineral water
[207] Other meat (dog, cat, etc)	[806] Onions	[1208] Schnapps, gin, whisky
Poultry and eggs	[807] Tomatoes (Fresh)	[1209] Palm wine, pito
[301] Chicken	[808] Tin tomatoes	[1211] Akpeteshie and local spirits
[302] Game birds	[809] Mushrooms	[1213] Beer and Guinness
[303] Eggs	[810] Other vegetables	[1215] Other beverages
[304] Other poultry	**Starchy Staples**	**Street Food**
Fish	[901] Cassava	[1301] Cooked rice and stew
[401] Crustaceans (lobster, crab)	[902] Cocoyam	[1302] Fufu and soup
[402] Fish	[903] Plantain	[1303] Emo Tuo (rice balls) and soup
[403] Fish (canned)	[904] Yam	[1304] Tuozafi and soup
[404] Fish (salted)	[905] Cassava dough	[1305] Banku and soup
[405] Other fish	[906] Gari	[1306] Kenkey
Milk	[907] Other starchy staples	[1307] Koko
[501] Fresh milk	**Pulses and Nuts**	[1308] Ampesi and stew
[502] Milk powder	[1001] Beans	[1309] Other prepared meal
[503] Baby milk	[1002] Groundnuts	
[504] Tinned milk	[1003] Palm nuts	
[505] Other milk products	[1004] Cola nuts	
Oils and Fats	[1005] Other pulses and nuts	
[601] Coconut oil		
[602] Palm kernel oil		
[603] Palm oil		
[604] Margarine/butter		
[605] Other vegetable oil and fats		

Table A3. Effect on Food as a Percentage of Total Expenditures

	(1)	(2)
	Percent Food	Percent Nutrient-Dense Food
LNS	-0.010	-0.004
	(0.007)	(0.005)
Constant	0.936***	0.411***
	(0.098)	(0.074)
N	1727	1727
Wald Chi^2	604.9	386.9
Prob > Chi^2	0.000	0.000

Significance codes: *** (p < .01), ** (p < .05), * (p < .1).
Notes: Dependent variables are (1) percentage of total expenditures made on food and (2) percentage of total expenditures made on nutrient-dense foods. Nutrient dense foods include animal-source foods, fruits, vegetables, pulses, and nuts. Controls for timing of enumeration relative to the birth of the target infant, enumerator, season and year of maternal enrollment into the trial, language primarily spoken at home, and maternal gestational age at enrollment, height, and education are included in the model (unreported). Cluster-robust standard errors in parentheses.

Table A4. Effect on Income - Expenditure Subsample

	(1)	(2)	(3)
	Per Capita Household	Target Mother	Husband
SQ-LNS	0.081**	0.048	0.086
	(0.037)	(0.056)	(0.055)
Constant	0.986*	1.351*	0.950
	(0.568)	(0.754)	(0.786)
N	1828	1844	1259
Wald Chi^2	201.544	214.188	148.615
Prob > Chi^2	0.000	0.000	0.000

Significance codes: *** (p < .01), ** (p < .05), * (p < .1).
Notes: Dependent variables are natural log of the inverse hyperbolic sine, $(yi+(yi^2+1)^{1/2})$, of daily: per capita household income, income of target mother, and income of target mother's husband. Controls for timing of enumeration relative to the birth of the target infant, enumerator, season and year of maternal enrollment into the trial, language primarily spoken at home, and maternal gestational age at enrollment, height, and education are included in the model (unreported). Cluster-robust standard errors in parentheses.

Table A5. Effect on Per Capita Daily Household Expenditures - Sibling Subsample

	(1) Food	(2) Nutrient-Dense Food	(3) Frequent Non-Food	(4) Infrequent Non-Food
SQ-LNS	0.067	0.084	0.148*	0.162*
	(0.053)	(0.060)	(0.084)	(0.085)
Constant	-0.173	-0.895	-1.883	-1.406
	(0.818)	(0.938)	(1.351)	(1.446)
N	621	634	612	599
Wald Chi^2	148.3	135.5	289.5	320.0
Prob > Chi^2	0.000	0.000	0.000	0.000

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

Notes: Dependent variables are natural log of (1) per capita total daily food expenditures, (2) per capita daily expenditures on nutrient-dense food, (3) per capita daily expenditures on frequently purchased non-food items, and (4) per capita daily expenditures on infrequently purchased non-food items. Nutrient dense foods include animal-source foods, fruits, vegetables, pulses, and nuts. Controls for timing of enumeration relative to the birth of the target infant, enumerator, season and year of maternal enrollment into the trial, language primarily spoken at home, and maternal gestational age at enrollment, height, and education are included in the model (unreported). Cluster-robust standard errors in parentheses.