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Article Title	Longitudinal analysis of the intrahousehold distribution of foods in rural Nepal: Relative variability of child dietary quality across age and sex cohorts
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Journal Title	*Food Policy*
Citation	Finaret, A. B., Miller, L. C., Joshi, N., Mahato, S., Lohani, M., Drozdowsky, J., & Rogers, B. L. (2018). Longitudinal analysis of the intrahousehold distribution of foods in rural nepal: Relative variability of child dietary quality across age and sex cohorts. Food Policy, 79, 101-110. doi:10.1016/j.foodpol.2018.06.003
Link to article on publisher's website	https://www.sciencedirect.com/science/article/pii/S0306919217309703?via%3Dihub#!
Version of article in FSC	Postprint
Link to this article through FSC	https://dspace.allegheny.edu/handle/10456/48109
Date article added to FSC	March 7, 2019
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Longitudinal analysis of the intrahousehold distribution of foods in rural Nepal: Relative variability of child dietary quality across age and sex cohorts

Abstract: Individual-level dietary data within households are rarely observed over extended periods of time, which limits our understanding of intrahousehold food allocation dynamics. This study explores whether and how dietary patterns of children within households changed over a four-year period in rural Nepal. Fixed-effects analysis of the panel data indicates that there are not disparities in dietary variability between girls and boys, but that there are disparities in dietary variability across age groups. Dietary quality, including as measured by animal sourced foods consumption, improves as children age, and the diets of older children are less likely to change as household diet changes. This stability may protect older children when household diets decline in quality, but older children are left out when household dietary quality improves. In contrast, younger children reap more gains relative to older children when household dietary quality improves, but also bear the brunt of food shortages when they arise. These results emphasize the importance of examining differences in dietary quality within households across age groups, especially for children over five years of age who are less likely to be targeted by international nutrition interventions and programs.

Keywords: intrahousehold food allocation; animal source foods; malnutrition; child dietary quality; Nepal

1. Introduction

Development programs and projects around the world aim to improve well-being in some way, such as through increased health, wealth, or knowledge. Community development interventions – especially those focused on agriculture – have great potential to improve child dietary quality in rural households (Ruel and Alderman 2013). These programs must operate not only in the context of diverse cultures, societies, and environments, but often also within complex intrahousehold resource allocation processes. The issue of intrahousehold dynamics is particularly relevant for those concerned with improving dietary quality and nutritional status. Food is typically a shared household resource, but different individuals within households have diverse calorie and micronutrient needs, depending on age, life-stage, disease status, and physical activity level.

Improving household access to resources is an important development and programmatic goal, but the dynamics of household decision-making are a key factor determining the success or failure of any intervention (Rogers 1990). Household resources may be inequitably distributed across different household members, especially during times when household circumstances are changing, such as due to fluctuations in incomes. For farming households, weather variability may also induce sudden changes in the intrahousehold allocation of resources. Despite the importance of within-household analyses, individual-level dietary data within households are rarely observed over extended periods of time, which limits understanding of within-household food distribution dynamics, especially in the context of impact evaluations (Berti 2012).

This study explores whether and how dietary patterns within households changed over a four-year period in the presence of a community-level development intervention in rural Nepal implemented by *Heifer International Nepal* (henceforth Heifer). The intervention from which the data for this study were collected has been demonstrated to improve both child health and child dietary quality in Nepal and elsewhere, and these results vary across different regions and versions of the intervention (Miller et al. 2014; Darrouzet-Nardi et al. 2016; Rawlins et al. 2014). Intervention activities were provided to specific areas within rural communities, and consisted of women's self-help groups which met regularly to promote community cohesion and self-reliance. Two meat-type goats were gifted to participating families at the end of the first year of the intervention. Further details about the intervention itself, and its impacts on dietary quality and child health can be found in Miller et al. (2014) and Darrouzet-Nardi et al. (2016). During the study period, data on both child-level and household-level dietary intake were collected, offering a unique opportunity to study intrahousehold dynamics over a 4-year period in a population at high risk of malnutrition and food insecurity.

This article does not focus on the impact of the *Heifer* intervention itself, but instead on the intrahousehold dynamics over the same study period. This central hypothesis of this article is that the intrahousehold allocation of foods – measured as relative responsiveness of child dietary diversity and animal sourced foods consumption to household dietary quality over time – in rural Nepal differed across sex and age cohorts. Differences in dietary quality response matter for child well-being, because even short periods of malnutrition can affect growth and development (Dewey and Begum 2011). There may be disparities in the levels of dietary quality at any single

point in time, or disparities in how dietary quality changes over time for different cohorts of children. This study focused on the latter possibility.

We found that there were disparities in the responsiveness of child dietary quality with respect to child age, but not child sex. Older children's dietary response is not as strong as for younger children, which indicates that they are protected during times of shortage but don't reap benefits during times of plenty for the household. Understanding age-based disparities in food consumption for children older than 5 years is essential because they are an under-studied cohort for which food and nutrition policies are not typically tailored.

2. Background

Although nutrition is improving in Nepal, inadequate child dietary quality is still a problem of public health significance, especially for rural families. Approximately 41 percent of the population in Nepal lives in rural areas (MOHP & ICF International 2016). The 2016 *Demographic and Health Survey* (DHS) in Nepal indicated that, for children aged 6 to 23 months of age, only 35% of them were fed a minimally acceptable diet in the 24-hours preceding the survey; 35.8% of children under age five were stunted, and 9.7% of children under age five were wasted (MOHP & ICF International 2016). These prevalence rates of undernutrition are still high, but have been improving over the past 20 years: 57% of children under age five in Nepal were stunted, and 15% of children were wasted in 1996.

These indicators stress the importance of understanding how households allocate constrained resources across different family members, especially children. This study utilizes a panel dataset

of children ranging from 6 months to about 13 years of age during the fourth year of data collection. Unfortunately, detailed and generalizable data on the health and nutritional status of children over age 5 but under age 15 are typically not collected by nationally representative surveys such as the DHS, and little attention is given to older children in the primary literature (Alam et al. 2010). This omission, although it may be necessary due to logistical and financial constraints of complex surveys, limits how much we know about the nutritional status and dietary quality of children over five years of age.

A long history of work in the applied economics, anthropology, sociology, nutrition, and public health literature has examined the intrahousehold dynamics around control of resources, particularly between sexes (Belachew et al. 2011). For example, a study in Bangladesh found nutritional discrimination against girls, as evidenced by 16 percent higher calorie consumption among boys compared with girls under age 5 (Chen 1981). Sex bias against girls may have been related to a lack of maternal empowerment (Trapp et al. 2004). However, other work has found evidence that contradicts gender bias against girls. In Nepal, there is evidence for sex bias against adult women, but not against girl children (Gittelsohn 1991). In Peru, there is some evidence for calorie bias against toddler-aged children with respect to their individual needs, but no differences across the sexes in the same population (Graham 1997). Some studies examine inequitable distributions in food quantities, which may miss the important aspect of dietary quality (Messer 1997).

A child's age may also affect how health inputs – such as food and healthcare – are allocated within households. In Nepal, age bias has been observed in parental perceptions of the severity

of childhood illness (Pokhrel and Sauerborn 2004). Evidence from rural Burkina Faso indicated that there was age bias in the allocation of healthcare resources, but not sex bias (Sauerborn et al. 1996). The authors hypothesized that it was optimal for households to allocate healthcare to those members of the household who were more economically productive (Sauerborn et al. 1996). There is evidence that mothers may protect the caloric intakes of the youngest household members during times of high food prices (Block et al. 2004; Kuku et al. 2011), but inaccurate parental perceptions of the food needs of younger children may contribute to inequitable distributions (Graham 1997). A literature review found that there was wide variation in relative caloric adequacy between age groups; depending on the setting, younger children were sometimes protected in terms of their caloric intake, but not always (Berti 2012).

Dietary diversity and animal sourced foods

We measure dietary quality in this study by dietary diversity, which is a count of the number of food groups from which an individual had consumed (Ruel 2003). Dietary diversity is a direct determinant of nutritional status, especially for key micronutrients such as vitamin A and iron, which are found predominantly in animal sourced foods (ASF) (Arimond et al. 2010; Arimond and Ruel 2004). Dietary diversity has been associated with child nutritional status and household food security, independent of income and socioeconomic status across many settings (Arimond and Ruel 2004; Hoddinott and Yohannes 2002). Dietary diversity is often measured using 24-hour recall data (Arimond et al. 2010). Recent evidence comparing biochemical nutritional markers with different dietary recall instruments indicates that 24-hour recalls and other simple indicators perform well at estimating nutrient intake (Prentice et al. 2011: Arimond et al. 2010).

Deriving actual nutrient intake from more detailed dietary surveys can also be quite informative, but is often fraught with measurement error for nutrients as well as for calories. Using dietary diversity as an outcome can help avoid those uncertainties.

Child dietary diversity scores (DDS), measured two ways, are two of the outcomes of interest; the third outcome of interest is a count of the types of ASF. Consumption of ASF, which are typically rare in the diet in this vulnerable setting, can signal that the household can occasionally afford them. Traditionally, the nutrition literature uses seven foods and food groups to calculate child dietary diversity (WFP 2010), but in the applied economics literature, other foods are often included, such as processed foods, spices, oils, tea, coffee, other beverages, and sweets. In the former case, dietary diversity is intended to indicate dietary quality only, whereas in the latter case, dietary diversity could encompass other aspects of well-being. For a holistic and multidisciplinary investigation, both indicators are analyzed for this study.

2.2 Elasticity of dietary diversity

Applied economics studies focusing on intrahousehold dynamics often estimate income and price elasticities of food consumption, to examine the relative stability of the diets of household members over time (Villa et al 2011, Behrman & Deolalikar 1990). Estimating elasticities is helpful for understanding responsiveness of consumption to changing incomes or prices. Elasticities can also be used to estimate how child diets respond to other variables besides income and prices; in the present study, we are interested in the effects of household-level dietary change on child-level dietary change. If the dietary response of an individual child is

elastic, it may signal that that child's food consumption or dietary quality is more volatile (Villa et al. 2011; Behrman and Deolalikar 1990; Alderman and Gertler 1997). In some cases, such as for adults with seasonally dependent physical labor to perform for their occupations, volatility in food consumption may be desirable because intake can more closely match caloric expenditure. If children's food consumption is nutritionally adequate, stable food consumption is preferable for optimal growth and development. Further, Alderman and Gertler (1997) demonstrated that, as household incomes increase, the income elasticity of consumption decreases.

3. Methods

This study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures involving human subjects/patients were approved by the *Nepal Health Research Council* (NHRC Reference #845, Renewal #1496), the human investigation review board in Nepal endorsed by the Office of Protection Office for Human Research Protections, U.S. Department of Health and Human Services, as well as the [Removed for blinding] *Institutional Review Board* and the [Removed for blinding] *Institutional Review Board*. Six rural communities of Nepal with predominantly agricultural livelihoods were selected to participate in the phased implementation of a community-level development intervention. Households (N=414 at baseline) and children (N=600 at baseline) were surveyed at six points over four years. The study was located in three districts of Nepal: Chitwan, Nawalparasi, and Nuwakot. Chitwan and Nawalparasi are both located in the Terai region of Nepal; Nuwakot is located in the Hills. These areas are largely populated by low-income subsistence farmers.

All members of each participating household were enrolled in the study, and participation rates exceeded 90% in each community. Households and children in each community were surveyed at baseline, and follow-up surveys were implemented at 6 months, 12 months, 18 months, 24 months, and 48 months, for a total of 6 time points. This study only utilizes data from the baseline, 12 month, 24 month, and 48 month time points because time-variant information on incomes, land holdings, and livestock herd sizes is available; this information was not available for the 6 month or 18 month time points. The presence of the intervention was controlled for in the analysis using a time trend. This variable is intended to control for the effects of the intervention across study sites over time that may have contributed to child dietary quality, such as increased community cohesion, social capital for women, and livestock transfers.

3.1 Measuring dietary quality for children and households

As part of the study, dietary intake and health of children >6 months of age who resided in participating households were assessed in detail. There were three outcomes of interest related to child dietary quality: (1) dietary diversity as measured by the World Health Organization (DDS-7), (2) dietary diversity as measured by the total count of food groups from which a participant consumed (DDS-17) and (3) animal sourced foods consumption (ASF). Once children were enrolled, they were followed throughout the study period. Children < 6 months of age were excluded, as they were likely to be exclusively breastfed (MOHP & ICF International 2016). The dietary intake questionnaire was answered by mothers, and was an individual 24-hour recall for each child over 6 months of years of age in the household.

The first dietary diversity score (DDS-7) was constructed by adding binary indicators of key food groups deemed as most important for nutritional status by the WHO (WHO 2010). These seven food groups are: starchy staples (grains or white potatoes); vitamin-A rich fruits and vegetables; other fruits and vegetables; organ meat, meat, and fish; eggs; legumes, nuts, and seeds; milk or dairy products (WHO 2010). This constructed indicator could range from one to seven. The second dietary diversity score (DDS-17) score was constructed by adding binary indicators of each of the seventeen foods in the original questionnaire. By construction, these variables, which serve as two of the three outcomes of interest in this study, are not independent from one another. These seventeen food groups were: grains or white potatoes; fresh animal milk, powdered milk; cheese and other dairy products; oil; legumes, nuts, and seeds; yellow-orange vegetables; green leafy vegetables; other fruits and vegetables; eggs; fresh or dried fish; beef, pork, lamb, goat, chicken, duck; liver, heart, or other organ meat; tea or coffee; sweets; processed foods such as biscuits or noodles; added sugar or ghee; commercially prepared infant foods. Thus, this indicator could range from one to seventeen. The third outcome of interest was an indicator of ASF consumption. This variable was constructed to be equal to the sum of each of the binary indicators for meat (beef, pork, lamb, goat, chicken, duck, fish, liver, heart, organ meat), eggs, and dairy products (fresh animal milk, powdered milk, milk products), and it could range from zero to three.

In addition to the child dietary data, respondents were asked about availability of the same foods in the household as a whole over the previous 24-hour period, which provided the data needed to measure household-level dietary diversity. Specifically, respondents were first asked about the food consumption for each child in the household, and then asked whether anyone else in the

household had consumed each food item. Using this information, three household-level dietary quality variables – household DDS-7, household DDS-17, and household animal sourced foods consumption – were constructed in parallel to the individual-level dietary quality variables using the same foods and food groups as the child-level dietary quality variables described above. The construction of this variable was designed to be as inclusive as possible in terms of measuring the foods that anyone in the household had access to. This variable construction likely creates an upward bias in coefficient estimates. Given that we are interested in the differences in coefficient estimates between cohorts and not in the coefficient estimates for establishing causal relationships of any kind, we were not concerned with this upward bias and only sought to examine the differences between what a child ate and what anyone else in the household ate.

Variation in household dietary quality over the course of data collection came in part from seasonal patterns in overall food availability and changes over a 4-year period in socioeconomic status of households (Darrouzet-Nardi et al. 2016). Other sources of variation such as agricultural output in each region may have also contributed to variation in household food availability, but this was not measured. These household-level variables serve as the main exposure variables for the analysis. The analysis does assume that household-level dietary quality is exogenous to the other variables in each regression model, and the goal of the analysis is not to determine the causal effect of household dietary quality on child dietary quality. Instead, the aim was to assess differences across age- and sex-cohorts in the estimated relationships between household-level dietary quality and child-level dietary quality. Measuring the causal effect of household dietary quality on child dietary quality would have required an experiment of some kind to address endogeneity problems.

3.2 Analysis

The analysis begins with two preliminary specifications of the relationships between household and child dietary quality. The first specification estimates the relationships between household- and child-level dietary quality, controlling for child age, sex, supplemental foods consumption, household socioeconomic status, region, and a time trend. The second specification estimates the relationships between livestock herd size and child-level dietary quality, controlling for those same covariates. The responsiveness of child-level dietary quality to livestock herd size was analyzed in addition because farming households often consume foods from their own livestock herds. To test the central hypotheses regarding the intrahousehold allocation of foods over time, Wald Tests were estimated to ask whether the β^j coefficients differ across key groupings of the study population (Wald 1945).

Equations 1 and 2 were estimated using Poisson regression or logistic regression, depending on whether the outcome being estimated was measured as count data or binary data, respectively. The first equation estimated the overall relationships between household dietary quality and child dietary quality, controlling for key household, child, and community characteristics. The second equation estimated the overall relationships between livestock herd size and child-level dietary quality, measured by our three constructed indicators described above as well as binary indicators of whether the child consumed any meat, eggs, or milk. The coefficient estimates can be interpreted as semi-elasticities. A semi-elasticity is the percentage by which consumption of a good changes when an explanatory variable changes by one unit. The coefficient estimates on

the logistic regressions are exponentiated to display odds ratios for the likelihood of the child consuming meat, eggs, or milk. Standard errors were clustered by family.

$$Diet_{iht}^{c} = \beta_j HHDiet_{ht} + \sum_{k=1}^{K} \beta^j H_t + \sum_{l=1}^{L} \beta^k C_t + \beta_m Trend + \mu_{iht}^{c} \quad (1)$$

$$Diet_{iht}^{c} = \beta_j Livestock_{ht} + \sum_{k=1}^{K} \beta^j H_t + \sum_{l=1}^{L} \beta^k C_t + \beta_m Trend + \mu_{iht}^{c} \quad (2)$$

Equation 3 below was estimated using a conditional fixed-effects Poisson regression model, so the β^j coefficient estimates can be interpreted as semi-elasticities. Thus, from estimates of β^j, the percentage by which the dietary diversity (or animal sourced foods) score changes when household dietary diversity (or animal sourced foods) score changes by one unit can be derived.

$$Diet_{iht}^{c} = \alpha_i^c + \sum_{j=1}^{J} \beta^j \left[HHDiet_{ht} * W_{iht} \right] + \sum_{k=1}^{K} \beta^k H_t + \sum_{l=1}^{L} \beta^l C_t + \mu_{iht}^{c} \quad (3)$$

In Equations 1 through 3 above, $HHDiet_{hrt}$ represents the household-level dietary diversity score, measured as either DDS-7 or DDS-17, or animal sourced foods score for each time period, t=1 through t=4. $Livestock_{ht}$ represents the size of the household's livestock holdings, measured in Global Livestock Units (FAO 2013). In these equations, the subscript *i* denotes individual children, *c* indicates a child-level variable, *h* denotes households, *t* denotes time periods, and *j* and *k* denote sets of coefficients to be estimated. This term was interacted with various sub-groupings of the study population, represented by W_{iht}, including by sex (boy children and girl children), age group (6-24 months, 25-48 months, 49-72 months, >72 months), and supplemental foods consumption (the child did consume supplemental foods such as breastmilk or infant foods, or did not). Child sex is not included in the semi-elasticity estimates because it is perfectly

collinear with the child-level fixed-effects. The household-level variables H_t included livestock herd size measured by global livestock units, and the socioeconomic score of the household which incorporates income and other factors influencing well-being such as floor type, roof type, furniture, and access to electricity. μ_{iht}^{c} is an independently and identically distributed error term. Child-level fixed-effects, indicated by α_i^c, were included to address any time-invariant, individual-level factors which influence the elasticity of child dietary quality. The child-level outcomes of interested are denoted by $Diet_{iht}^{c}$.

To test the central hypotheses regarding the intrahousehold allocation of foods over time, Wald Tests were performed to ask whether the β^j coefficients differed across key groupings of the study population (Wald 1945). The semi-elasticity estimates and tests for differences in coefficients across different demographic and geographic cohorts were stratified into three groups: by sex, by age group, and by whether the child had consumed supplementary foods such as breastmilk or commercially prepared infant foods. Thus, we can test for disparities in the responsiveness of child dietary diversity and in child dietary quality across various cohorts with the following hypothesis test in Equation 4 below:

$H_o : \beta_1^j = \beta_2^j ... = \beta_J^j \ \ \forall \ \mathrm{J} \in (1,...J)$, where J is the number of W_{ihrt} cohorts. (4)

H_A : At least one $\beta_1^j \neq \beta_2^j$ for some $\mathrm{J} \in (1,...J)$.

4. Results

The panel data resulting from the four years of data collection were analyzed using Stata/MP version 14.0 (StataCorp 2015). Household-level descriptive statistics of the sample at baseline are presented in Table 1. Mean household dietary diversity was 2.54 food groups, which is less than the minimum recommended for children of four food groups per day. When counted using the DDS-17 measure, households on average consumed from 4.20 food groups in the 24-hour period before the survey. No households consumed more than 6 food groups when measured using traditional DDS-7 measure, and no households consumed more than 10 food groups when measured using the expanded DDS-17 measure. There was a wide range in annual incomes, livestock herd sizes, and land holdings across the study population.

[Insert Table 1 about here]

Table 2 first outlines child dietary data at baseline, stratified by age and sex, and then stratified by year of the study so as to examine changes over time. T-tests for differences across age groups within sexes suggest that there are not disparities in DDS-7 at baseline, but that there are disparities in DDS-17 and ASF at baseline between older and younger children. Older girls have a slightly higher average consumption of DDS-17 ($p=0.001$) and a slightly lower consumption of ASF ($p=0.001$) than younger girls, and a similar pattern holds for older boys and younger boys. Over time, all three indicators see slight improvements, but disparities in ASF consumption between older and younger children of both sexes remained even by the fourth year of the study ($p=0.001$).

[Insert Table 2 about here]

Table 3 presents estimates of the semi-elasticities of child dietary quality with respect to household dietary quality. The resulting estimated coefficients are later tested to ascertain if there

are differences in dietary quality responsiveness across cohorts of interest in Tables 5 through 7 below. Overall, changes in children's dietary quality over time reflect those changes in household dietary quality. There are positive and statistically significant relationships between household and child dietary quality measured by the three indicators. Child ASF consumption is the most responsive to household ASF consumption compared to other indicators of household dietary quality. A one-unit increase in household ASF consumption increases child ASF consumption by 97.5% $\left(\hat{\beta}^j = 0.975, se = 0.032\right)$. Child dietary quality is least responsive to household dietary quality when both are measured using DDS-17. A one unit increase in household-level DDS-17 increases child-level DDS-17 by 15.5% $\left(\hat{\beta}^j = 0.155, se = 0.006\right)$. A one-unit increase in household-level DDS-7 increases child-level DDS by 29.5% $\left(\hat{\beta}^j = 0.295, se = 0.011\right)$.

These relationships hold even after controlling for other key determinants of child-level dietary quality. There are no strong empirical patterns in the relationship between livestock herd size or socioeconomic scores and child-level dietary quality, nor between child sex and child-level dietary quality. Child age has a small but statistically significant and positive association with increased consumption of DDS-17, but not with other dietary quality indicators. The consumption of supplemental foods is positively and significantly related to child-level dietary quality, but only for the DDS-17 indicator. When measured by ASF, child-level dietary quality is negatively associated with living in the Terai region. The time trend is positively associated with child-level dietary quality, indicating that something over time was helping to improve diets. The passing of each additional year improved DDS-7 by 2.6% $\left(\hat{\beta}_m = 0.026, se = 0.012\right)$ and improved

DDS-17 by 5.7% $\left(\hat{\beta}_m = 0.057, se = 0.009\right)$. That the latter improved faster is consistent with other empirical evidence about the elasticities of luxury goods versus necessary goods. Small improvements in well-being can lead to larger relative increases in consumption of luxury goods at lower income levels while the responsiveness of necessary goods to improvements in well-being is slower and steadier. This reflects preferences for diversity in the diet and for enjoyment of food beyond just sustaining a person nutritionally.

[Insert Table 3 about here]

Table 4 below estimates the same models as Table 3 above, except that the main explanatory variable is not household-level dietary quality, but instead is livestock herd size as measured by animal score. The semi-elasticities of child-level dietary quality with respect to livestock herd size are smaller in magnitude compared with the semi-elasticities with respect to household-level dietary quality. A one-unit increase in the animal score increases DDS-7 by 1.2% and increases ASF by 3.1%. The animal score of a household is not associated with child-level DDS-17, which is consistent with the construction of the DDS-17 variable, for which no animal sourced foods are included that are not also included in DDS-7. Interestingly, the odds of a child having consumed flesh foods, which includes meat, fish, and offal (OR=0.942, se=0.024) and eggs (OR=0.926, se=0.038) are lower for those households with a higher animal score. In contrast, animal scores are positively and significantly related to child-level milk consumption (OR=1.344, se=0.043). This indicates that perhaps these households are selling meat and eggs instead of consuming them within the household or combining these strategies, and that milking animals are utilized for within-household consumption.

[Insert Table 4 about here]

Table 5 presents estimates of the relationships between household- and child-level dietary quality across sex cohorts. In these regressions, each household-level dietary quality indicator was interacted with binary indicators for boy child and girl child, respectively, so as to test the differences between those coefficient estimates using Wald Tests, the results of which are summarized in the top three rows of the Tables 5 through 7. There are no differences in estimated elasticity of child-level dietary quality between girl children and boy children. A one-unit increase in household-level DDS-7 is expected to increase child-level DDS-7 by 30.3% for boy children and 29.2% for girl children, but this small difference in magnitude is not statistically significant. Similarly, a one-unit increase in DDS-17 is expected to increase child-level DDS-17 by 13.6% for boy children and 15.5% for girl children, but this difference is not statistically significant. The same pattern holds for dietary quality as measured by animal sourced foods consumption. The estimated coefficients on the control variables in these models indicate that there are positive relationships between child age and child-level dietary quality, even after controlling for the time trend as well. Overall, we cannot reject the null hypothesis for the Wald Tests in Equation 4 above that the coefficients are equal across sex cohorts; thus, there do not appear to be differences in the dietary quality variability between girl and boy children in these study sites.

[Insert Table 5 about here]

Table 6 below presents estimates of the same models presented in Table 3, but stratified by age

groups instead of by sex cohorts. Here, the magnitudes of the relationships between household- and child-level dietary quality are similar to those estimated in previous models, ranging from about a 15% response in DDS-17 to about a 100% response in ASF consumption. Overall, the magnitudes of the semi-elasticities decrease with age, and there are important differences in these estimates across age groups. For example, for a child aged 6 to 24 months, a one-unit increase in household-level DDS-17 is associated with an 18.8% increase in child-level DDS-17 consumption, but for a child 8 years old or older, only a 6.6% increase in child-level DDS-17 consumption can be expected. Similar patterns hold for DDS-7 consumption, although the differences in magnitude are not as striking; the youngest children see a 28.2% improvement in DDS-7 if household DDS-7 increases by one unit, and the oldest children see a 29.8% improvement. For ASF consumption, the youngest children see a 147% increase in their own ASF consumption if household ASF improves by one-unit, and the oldest children only see a 63.9% increase in their own ASF consumption.

Overall, child diets are highly responsive to changes in household animal sourced foods consumption, but less responsive to changes in overall household dietary diversity. This finding reflects the nature of animal sourced foods in this setting as luxury items. Based on the Wald Tests, we can reject the null hypotheses in Equation 4 above that the coefficients are equal across age groups. Thus, there are significant differences across age groups in the degree to which child dietary quality reflected that of the household. These patterns hold even after controlling for whether the child consumed supplemental foods, and after controlling for trends over time.

[Insert Table 6 about here]

Table 7 below presents estimates of the responsiveness of child dietary quality with respect to household dietary quality, stratified by whether the child had consumed supplemental foods. This indicator of supplemental foods consumption could be considered a proxy for child age, given that the main supplemental food as defined here is breastmilk. The other two supplemental foods included in the indicator are commercially prepared baby food and added ghee or sugar to make other foods more energy-dense for the child. There are no statistically significant differences in dietary response between children who had supplemental foods and those who did not when dietary quality is measured by DDS-7 or ASF. There may be small differences in dietary response when dietary quality is measured by DDS-17. A one-unit increase in household-level DDS-17 is associated with a 15.3% increase in child-level DDS-17 for those children who were supplemented and a 14.1% increase in child-level DDS-17 for those children who were not supplemented, and this difference is statistically significant ($p=0.04$). However, the magnitude of this difference is not large enough to be meaningful. Overall, based on the Wald Tests, we cannot reject the null hypotheses in Equation 4 above that the coefficients are equal across groups of children consuming supplemental foods and not. Given that there the differences in dietary response across groups of children who were given supplemental foods or not were negligible, some factor besides supplemental foods may be influencing the disparities across age groups.

[Insert Table 7 about here]

Based on the analysis of semi-elasticities, there is evidence of disparities in relative variability

over time of child dietary quality with respect to household dietary quality in these study sites. These disparities occur across age groups of children, but not across sexes or across groups of children who had consumed supplemental foods or not. However, given that there are positive associations between child age and child dietary quality throughout the estimates presented above, a closer look is required to understand the differences between older children and younger children. Table 8 below presents the bivariate relationships between dietary quality and child age, as well as the same relationships after controlling for the time trend. Before controlling for the time trend, an additional month of age is associated with a 0.3% increase in child-level dietary quality when measured by DDS-7, a 0.6% increase when measured by DDS-17, and a 0.7% increase when measured by ASF. After controlling for explanatory factors that change over time, the relationship between DDS-7 and age disappears. For DDS-17 and ASF, an additional month of age improves child-level dietary quality by 0.6% and 1.8% respectively in this model specification. Given this evidence, as well as the small differences in semi-elasticity magnitudes across age groups presented in Column 1 of Table 6 above, it appears that differences in child dietary quality across age groups come mainly from differences in food groups other than the basic ones[1], such as oil, tea or coffee, sweets, or processed foods such as biscuits or noodles, or in animal sourced foods consumption on its own.

[Insert Table 8 about here]

Taken together, the evidence suggests that dietary quality increases with age in this population,

[1] Basic food groups included: Starchy staples; vitamin-A rich fruits and vegetables; other fruits and vegetables; organ meat, meat, and fish; eggs; legumes, nuts, and seeds; milk or dairy products (WHO 2010).

and that the diets of younger children are more responsive to changes in the diet of the household as a whole. This pattern is a benefit to younger children when household circumstances are improving, but younger children also bear the brunt declines in of household-level dietary quality. Similarly, older children may be left out of gains in household-level dietary quality, but they are relatively more protected against potential declines. These relationships hold after controlling for whether the child had been consuming supplemental foods such as breastmilk or commercially prepared infant foods.

5. Discussion

Particularly in these study sites of Nepal, where average dietary quality is low and there are substantial fluctuations in food availability across the seasons, examining the intrahousehold allocation of foods is crucial. In the public health and medical anthropology literature, child age is not examined as often as sex as a potential risk for inequitable intrahousehold distributions, and this study sought to fill this gap. Age-based discrimination has been found between adults and children (Senauer et al. 1988), but evidence of age-based discrimination between children of different ages within households is lacking. The empirical findings outlined above suggest that dietary quality, as measured by dietary diversity, is positively associated with child age. Child dietary quality has been found to increase with age in other settings (Abdullah and Wheeler 1985). However, this finding is only part of the story. Over time, the stability of diets also matters for child health, especially because short periods of poor diet that overlap with key child development periods can increase risks of disease and undernutrition.

We found no measurable disparities in the degree to which children's dietary quality mirrors that of their households across cohorts of sex or across children with and without supplemental food consumption. There has been evidence of sex bias in the intrahousehold allocation of foods in Nepal and elsewhere (Behrman and Deolalikar 1990; Alderman and Gertler 1997), but we do not see that here. However, the stability of children's diets in this setting was different depending on their ages. For younger children, the responsiveness of their own dietary quality to household dietary change is much larger than for older children. This is a benefit to younger children during times of plenty, but may be harmful during times of food shortages. The opposite challenge arises with older children, whose diets are much less responsive to household dietary change. Similar patterns between older and younger children have been found in India, although these analyses are not recent (Gopaldas et al. 1983; Basu et al. 1986). Further anthropological or sociological investigations into these allocative decisions may illuminate why the diets of younger children are more volatile in this at-risk setting.

This finding is surprising because the needs for a diverse diet are the same across all child age groups. Recommendations for adequate meal frequency decrease and recommendations for total energy needs increase as children age, but all children, regardless of age, should consume a diverse diet for optimal health. For a 6-month old child just beginning the complementary feeding stage, this might involve very small amounts of food from each food group, such as a few well-cooked legumes or a spoonful of pureed vegetables, for which the main purpose of offering during infancy is to allow the child to practice eating solid foods. Any amount of each food from the dietary diversity indicator is sufficient to qualify as helping the child achieve minimum dietary diversity (Daelmans et al. 2009). Starting at 6-months of age, the definition of

minimum dietary diversity is having consumed from at least four food groups in the previous 24-hour period (WHO 2010).

A potential explanation for different dietary patterns across age groups is that younger children are more likely to be breastfed, providing some nutritional protection, which families recognize as beneficial. However, differences between age cohorts were found even after controlling for whether the child was consuming supplemental foods such as breastmilk, and disparities were not found across groups of children who consumed supplemental foods and those who did not. Thus, something other than supplementation with breastmilk or commercially prepared infant foods is driving the dietary stability differences between age groups of children. For example, when there is plenty of food available, families may decide to invest proportionally more in their youngest children because of their inherent vulnerability. In rural Nepal, previous work has demonstrated that families do protect their youngest children from food stress (Panter-Brick 1993).

Another potential explanation for why the diets of younger children are systematically less diverse than the diets of older children is simply that the demanding dietary needs of infants and young toddlers relative to their sizes are not fully recognized by caregivers. Despite their small relative sizes, growth occurs fastest for the youngest cohorts, but it is somewhat paradoxical that they need more calories and nutrients per kilogram of body weight than an adult does. This may may be an obstacle for families when they plan meals, especially in the face of scarcity. Evidence for this has been seen in Bangladesh (Abdullah and Wheeler 1985). The patterns found

may also be related to the increasing autonomy of children as they age, as older children have more potential to try to smooth their food consumption throughout the year on their own, whereas infants and young toddlers have comparably less autonomy to do so. For example, older children could have more easily consumed foods outside the home, such as at school, without the knowledge of the respondents, compared to younger children.

5.1 Strengths and limitations

The strengths of this study include that it was longitudinal, that children up to age 13 years were included in the dietary data collection, and that there was a clear delineation in the survey between household-level and child-level food consumption. A main limitation of this study was that underlying causes of the patterns found – such as improved nutrition knowledge over time – were not examined. Another limitation is that there may have been recall bias and reporting bias in the child-level dietary data, given that the parents responded for the children and that even the best efforts may misremember what happened on the previous day. Future work should seek to measure food consumption as objectively as possible, however financial and logistical constraints often prevent this. Given that the intervention itself did not focus on nutrition or food intake, and instead was focused on broad-based community-level development, we expect that respondents were not 'primed' to answer survey questions about dietary intake of children in any particular ways, but there is always the possibility of recall or reporting biases in surveys like this one. We also expect that recall bias was minimal because the dietary data collection asked about consumption in the past 24-hours. However, other challenges arise when using 24-hour

recall data, for example, the day of the week may matter more if certain foods are typically consumed on certain days, like meat.

One potential cause of the patterns found is changes in women's empowerment due to the community-development intervention present in these communities over the course of the study period. Previous work has demonstrated that much of the improvement in child dietary quality over the four-year study period can be attributed to the community-development intervention, which focused on women's participation in self-help groups (Darrouzet-Nardi et al. 2016, Miller et al. 2014). Related work has found that if adult women control the household resource in question, consumption patterns that favor children follow (Rogers 1996: Jin and Iannotti 2014), but these findings do not address food allocations across siblings or across children of different ages. In Nepal specifically, women's land and livestock ownership was associated with their empowerment, and this empowerment was associated with their children's health (Allendorf 2007). Thus, increased social standing for women could lead to better child dietary outcomes, potentially through an improved distribution of food within the household, including an outward shift of the demand curve for food for children. Indicators of women's empowerment were not measured in the study. Field trials and community development projects should regularly measure key variables through which interventions and programs are expected to cause improvement in outcomes of interest.

5.2 Conclusion and policy implications

Applied economics studies focusing on intrahousehold dynamics typically estimate income and price elasticities of dietary quality to examine the relative stability of the diets of household

members over time (Villa et al 2011, Behrman & Deolalikar 1990). This study used a different determinant of food availability to children: the food availability in their respective households. To understand intrahousehold allocations in this study population, we estimated the responsiveness of child-level dietary quality to changes in household-level dietary quality. In rural Nepal, child-level dietary quality is highly and positively related to household-level dietary quality, as would be expected. Child-level dietary quality is more inelastic when measured by dietary diversity, and more elastic when measured by animal sourced foods consumption, patterns which are consistent with animal sourced foods being luxury goods in this setting. The stability of dietary diversity over time depended on the age of the child, which was concerning given that all children have the same nutritional requirement for a diverse diet. We do not necessarily expect these findings to apply elsewhere. The nuances of intrahousehold allocation decisions are diverse and wide-ranging across different populations around the world, and these findings serve to exemplify that fact, as well as encourage the careful observation of children, especially older children, within households in other settings.

There are two key policy implications of our findings. The first is that measuring intrahousehold resource allocation, especially during health and community development interventions, is essential to understand the determinants of child health. Another policy implication is that the diets of older children should not be ignored in data collection. Children older than age 5 are often not explicitly prioritized during health, nutrition and community-development interventions, because resources are scarce and donors want to invest where the benefit-to-cost ratios are highest. This prioritization may make financial and even moral sense to some. However, especially in the cases of holistic community-development interventions, investment in

public goods such as roads, sanitation, education, and government policies which encourage the production and consumption of goods or services with positive health externalities, prioritizing a specific cohort of children based on benefit-to-cost ratios may be a barrier to progress in eliminating nutritional deficiencies.

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Table 1: Household descriptive statistics at baseline

Variable *N=**414 total households***	Mean	Standard Deviation	Minimum	Maximum
Income (Nepali rupees per year)	66,794	45,188	10,000	250,000
Animal Score (GLU)	2.11	1.77	0	7.75
Land (m^2)	3,587	4,335	128	33,900
Household DDS (Count; possible range 1-7)	2.54	0.64	1	6
Household DDS (Count; possible range 1-17)	4.20	1.52	2	10
Household ASF (Count; possible range 0-3)	0.62	0.64	0	3

Notes: Animal scores are measured in Global Livestock Units (FAO 2013).

Table 2a: Child dietary characteristics by age, sex, and year

Child Characteristics Units	***N* Children**	*DDS* Count of foods (range 1-7)	*DDS-17* Count of foods (range 1-17)	*ASF* Count of foods (range 0-3)	*Supplementing* % of total
Girl children, < 60 months					
Mean	**177**	2.58	4.73	0.69	54.9%
SD		1.06	1.92	0.67	-
Girl children >= 60 months					
Mean	**118**	2.73	4.86	0.30	5.4%
SD		1.08	1.74	0.55	-
t-test p-value		0.27	0.001***	0.001***	-
Boy children <60 months					
Mean	**181**	2.71	4.91	0.72	62.4%
SD		1.05	1.75	0.71	-
Boy children >=60 months					
Mean	**124**	2.46	4.55	0.26	2.3%
SD		1.08	1.69	0.54	-
t-test p-value		0.32	0.001***	0.001***	-
All children – Baseline					
Mean	**600**	2.62	4.77	0.45	25.4%
SD		1.07	1.79	0.64	-
t-test p-value		0.57	0.42	0.001***	-
All children – Year 1					
Mean	**746**	2.67	4.21	0.46	23.0%
SD		1.18	2.15	0.66	
t-test p-value		0.009***	0.001***	0.001***	
All children - Year 2					
Mean	**841**	2.98	4.23	0.49	19.2%
SD		1.05	2.47	0.63	
t-test p-value		0.132	0.001***	0.001***	
All children – Year 3					
Mean	**760**	2.98	5.99	0.73	21.6%
SD		1.15	2.02	0.74	
t-test p-value		0.805	0.533	0.001***	

Notes: Two-sample t-tests with equal variances were performed to test the differences in means within sexes between age groups, and then for the sample as a whole at each time point of data collection between children <60 months of age and children >= 60 months of age. The null hypothesis for the t-tests was that the difference in means between younger and older children was not greater than zero; * p<.10, ** p<.05, *** p<.01.

Table 2a: Child characteristics by age and district at baseline

Child Characteristics		*Income*	*Land*	*Household size*	*Women's Education*	*Caste*
Units	N	*Nepali Rupees/year*	*m^2*	*Number of people*	*% with no formal education*	*% members of disadvantaged Caste*
6-24 months						
Chitwan	25	63,666 (47,524)	1,761 (2,130)	6.41 (2.32)	96.00	92.00
Nuwakot	54	70,720 (60,272)	4,008 (2,832)	8.56 (4.18)	97.92	98.15
Nawalparasi	38	88,831 (52,805)	6,529 (7,080)	10.65 (4.38)	96.97	89.47
Age group total	117	75,353 (55,700)	4,462 (4,998)	8.81 (4.21)	97.17	94.02
25-48 months						
Chitwan	43	60,475 (38,666)	1,809 (1,951)	6.58 (3.72)	95.00	86.05
Nuwakot	72	65,371 (50,991)	3,799 (3,090)	8.14 (4.01)	97.01	94.44
Nawalparasi	58	73,603 (48,686)	3,817 (5,093)	8.83 (3.51)	96.15	94.83
Age group total	173	66,889 (47,452)	3,332 (3,742)	7.92 (3.18)	96.23	92.49
49-72 months						
Chitwan	39	62,762 (42,772)	2,727 (4,336)	6.86 (3.18)	97.06	84.62
Nuwakot	58	60,913 (40,947)	3,802 (2,950)	8.24 (4.25)	96.23	94.83
Nawalparasi	58	70,750 (44,869)	4,100 (5,847)	8.80 (4.37)	95.92	93.10
Age group total	155	65,014 (43,072)	3,666 (4,544)	8.11 (4.11)	96.32	91.61
73-96 months						
Chitwan	45	70,093 (40,615)	2,022 (2,824)	6.25(3.34)	97.56	84.44
Nuwakot	54	69,415 (46,413)	3,438 (2,404)	7.69 (3.40)	78.72	100.00
Nawalparasi	60	71,530 (46,449)	4,549 (6,352)	9.33 (4.64)	80.39	100.00
Age group total	159	70,378 (44,567)	3,495 (4,513)	7.89 (4.06)	84.89	95.60
>96 months						
Chitwan	97	64,718 (45,582)	2,147 (2,595)	9.93 (6.45)	93.33	8486.60
Nuwakot	128	65,981 (52,439)	4,289 (3,485)	10.42 (4.72)	94.07	97.66
Nawalparasi	126	73,230 (47,145)	5,292 (6,457)	10.36 (3.91)	93.81	88.10
Age group total	351	67,922 (49,009)	4,127 (4,689)	10.19 (5.00)	93.77	91.17
All children						
Chitwan	249	64,524 (42,913)	2,113 (2,867)	7.57 (4.73)	95.22	86.35

Nuwakot	366	66,222 (50,526)	3,933 (3,071)	8.88 (4.35)	93.39	96.99
Nawalparasi	340	74,544 (47,665)	4,821 (6,208)	9.61 (4.18)	92.62	92.35
Grand total	955	68,627 (47,868)	3,821 (4,512)	8.79 (4.46)	93.61	90.16

Notes: For the purposes of this table, “Disadvantaged Caste” was defined as either Dalit or Janajati.

Table 3: Child-level and household-level factors associated with child dietary quality

Variable	Units	(1) DDS-7 WHO	(2) DDS-17 All foods	(3) ASF 0-3
Household DDS	Score	0.243***		
		(0.021)		
Household all foods	Score		0.165***	
			(0.006)	
Household ASF	Score			0.775***
				(0.043)
Child-level factors				
Child is male	Binary	-0.007	-0.007	0.012
		(0.040)	(0.019)	(0.054)
Child's age	Months	0.004	0.004***	0.006
		(0.003)	(0.001)	(0.004)
(Child's age)^2	Months	-0.000	-0.000**	-0.000
		(0.000)	(0.000)	(0.000)
Child consumed breastmilk	Binary	0.047	0.037	0.066
		(0.080)	(0.035)	(0.101)
Household factors				
Number of children in household <age 13 y	Count	-0.017	-0.026**	0.009
		(0.023)	(0.011)	(0.032)
Number of adults in household	Count	0.002	0.001	0.001
		(0.005)	(0.003)	(0.008)
Log(Socioeconomic score)	Continuous	0.004	-0.008	0.018
		(0.016)	(0.006)	(0.017)
Household located in Terai region	Binary	0.038	0.021	-0.061
		(0.045)	(0.021)	(0.058)
Animal score	Global livestock unit	-0.002	0.003	0.000
		(0.012)	(0.006)	(0.016)
Constant	Constant	0.271	0.790***	-1.129***
		(0.168)	(0.072)	(0.201)
N		735	2214	1388

Coefficients were estimated using Poisson regression. The outcomes of interest were child-level dietary diversity (DDS-7, Column 1), child-level consumption of all foods in the household (DDS-17, Column 2), and child-level animal sourced foods consumption (Column 3). Standard errors in parentheses (clustered by family); * p<.10, ** p<.05, *** p<.01.

Table 4: The relationships between household-level dietary quality and household-level dietary quality, with child and family fixed-effects

Variable	Units	(1) DDS-7 WHO	(2) DDS-17 All foods	(3) ASF 0-3	(4) DDS-7 WHO	(5) DDS-17 All foods	(6) ASF 0-3
Fixed-effects		Child	Child	Child	Family	Family	Family
Household DDS	Score	0.251***			0.242***		
		(0.044)			(0.041)		
Household all foods	Score		0.113***			0.115***	
			(0.007)			(0.007)	
Household ASF	Score			0.777***			0.773***
				(0.073)			(0.069)
Child-level factors							
Child is male	Binary				-0.002	0.017	0.015
					(0.052)	(0.024)	(0.070)
Child's age	Months	-0.004	0.001	0.012	0.002	0.004***	0.004
		(0.029)	(0.008)	(0.032)	(0.003)	(0.001)	(0.003)
(Child's age)^2	Months	-0.000	-0.000*	-0.000	-0.000	-0.000***	-0.000
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Year fixed-effects							
Year 1	Binary	-0.421	-0.237	0.198	-0.063	-0.156***	-0.182*
		(1.402)	(0.369)	(1.551)	(0.073)	(0.029)	(0.093)
Year 2	Binary	-0.243	-0.215	0.250	0.027	-0.157***	-0.023
		(1.045)	(0.276)	(1.163)	(0.107)	(0.028)	(0.099)
Year 3	Binary	-0.219	-0.149	0.199	-0.037	-0.112***	0.001
		(0.678)	(0.178)	(0.748)	(0.078)	(0.025)	(0.086)
N	N	437	2388	1225	746	2582	1442

Coefficients were estimated using fixed-effects Poisson regression. The outcomes of interest were child-level dietary diversity (DDS-7, Columns 1 and 4), child-level consumption of all foods in the household (DDS-17, Columns 2 and 5), and child-level animal sourced foods consumption (Columns 3 and 6). Standard errors in parentheses (clustered by family); * p<.10, ** p<.05, *** p<.01. Year 4 was omitted for perfect collinearity.

Table 5: The relationships between household-level dietary quality and household-level dietary quality, with child and family fixed-effects and interaction terms for age groups

Variable	Units	(1) DDS-7 WHO	(2) DDS-17 All foods	(3) ASF 0-3	(4) DDS-7 WHO	(5) DDS-17 All foods	(6) ASF 0-3
Fixed effects		Child	Child	Child	Family	Family	Family
Household dietary quality	Score	0.232***	0.206***	1.346***	0.229***	0.149***	0.940***
		(0.063)	(0.012)	(0.127)	(0.047)	(0.010)	(0.090)
Age 25mos.-48mos.*Household dietary quality	Interaction	0.015	-0.010	-0.095	0.008	0.018***	0.049
		(0.038)	(0.008)	(0.112)	(0.025)	(0.007)	(0.079)
Age 49mos.-72mos.*Household dietary quality	Interaction	0.017	-0.048***	-0.436***	0.013	0.010	-0.043
		(0.043)	(0.009)	(0.117)	(0.023)	(0.007)	(0.078)
Age 73mos.-96mos.*Household dietary quality	Interaction	0.022	-0.084***	-0.711***	0.017	-0.003	-0.114
		(0.055)	(0.011)	(0.132)	(0.024)	(0.007)	(0.079)
Age>96mos.*Household dietary quality	Interaction	0.010	-0.138***	-1.154***	0.012	-0.044***	-0.560***
		(0.071)	(0.013)	(0.149)	(0.026)	(0.008)	(0.080)
Year 1	Binary	-0.091	-0.544***	-1.007***	-0.070	-0.308***	-0.671***
		(0.125)	(0.036)	(0.107)	(0.072)	(0.028)	(0.085)
Year 2	Binary	0.091	-0.459***	-0.775**	0.080	-0.307***	-0.540*
		(0.354)	(0.085)	(0.306)	(0.309)	(0.081)	(0.291)
Year 3	Binary	-0.057	-0.343***	-0.344***	-0.038	-0.275***	-0.193**
		(0.094)	(0.026)	(0.093)	(0.080)	(0.025)	(0.088)
Child is male	Binary				-0.001	-0.014	-0.051
					(0.052)	(0.024)	(0.068)
Log(Socioeconomic score)	Continuous	-0.023	-0.003	0.027	-0.015	-0.004	0.039
		(0.083)	(0.021)	(0.074)	(0.074)	(0.020)	(0.071)
Animal score	GLU	-0.012	-0.006	0.026	-0.010	-0.012	0.013
		(0.040)	(0.011)	(0.037)	(0.036)	(0.010)	(0.035)
N		413	2469	1460	728	2584	1740

Coefficients were estimated using fixed-effects Poisson regression. The outcomes of interest were child-level dietary diversity (DDS-7, Columns 1 and 4), child-level consumption of all foods in the household (DDS-17, Columns 2 and 5), and child-level animal sourced foods consumption (Columns 3 and 6). Standard errors in parentheses (clustered by family); * p<.10, ** p<.05, *** p<.01. Year 4 was omitted for perfect collinearity.