ANIMAL SOURCED FOODS AND CHILD STUNTING

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Stunting affects 160 million pre-school children globally with adverse life-long consequences. While work within nutritional science suggests that stunting in early childhood is associated with low intakes of animal-sourced foods (ASFs), this topic has received little attention from economists. We attempt to redress this omission through an analysis of 130,432 children aged 6–23 months from 49 countries. We document distinctive patterns of ASF consumption among children in different regions. We find evidence of strong associations between stunting and a generic ASF consumption indicator, as well as dairy, meat/fish, and egg consumption indicators, and evidence that consuming multiple ASFs is more advantageous than any single ASF. We explore why ASF consumption is low but also so variable across countries. Non-tradable ASFs (fresh milk, eggs) are a very expensive source of calories in low-income countries and caloric prices of these foods are strongly associated with children's consumption patterns. Other demand-side factors are also important, but the strong influence of prices implies an important role for agricultural policies—in production, marketing and trade—to improve the accessibility and affordability of ASFs in poorer countries.

Key words: Animal-sourced foods, dietary diversity, fisheries, livestock, nutrition, stunting.

JEL codes: I15, O15, Q18.

Approximately 160 million children under the age of 5 and living in developing countries are considered chronically undernourished or stunted (de Onis and Branca 2016). That is, their height is at least two standard deviations less than the median height of a well-nourished child of the same age and sex. Nutritional status is a component of health and thus reducing chronic undernutrition has intrinsic value. In addition, chronic undernutrition in early life is causally linked to adverse later-life economic outcomes, including reduced schooling, poorer cognitive skills, lower earnings and a higher likelihood of living in poverty (Hoddinott, Rosegrant, and Torero 2013).

Most stunting manifests in the first 1,000 days of life (Victora et al. 2010). In many countries children are born small, partially protected from infections and low nutrient diets by predominant breastfeeding in the first few months after birth, but then subject to accelerated growth faltering from 6–24 months. Several things need to happen in this 6–24-month period to ensure that growth faltering does not take place. First, since breast milk can no longer provide all nutrients required for healthy growth and development, starting around the age of 6 months, children need to be introduced to complementary foods that have to be provided frequently (because of small gastric capacity) and fed a nutrient-rich diet (or fortified complementary foods) to ensure that they meet their nutrient requirements. Second, because young children's immune systems are in development, they need to be

protected from both acute and chronic infections through preventative measures (e.g., improved water, sanitation, hygiene, food safety, immunization) and optimal use of health services for timely treatment. After 24 months, further growth faltering is less commonplace as immune systems strengthen, but in developing country contexts there is also little evidence of systematic catch-up growth in the first 5 years of life, and stunting tends to be highly persistent at a population level (Leroy et al. 2014).

While there is broad agreement on the important general interplay between diets, health, and care practices, thinking on the importance of specific nutrient dimensions of child undernutrition has evolved over time. In the post-war period, substantial emphasis was placed on protein deficiency as one of the main causes of undernutrition in low-income countries (Semba 2016), but an influential article by McLaren (1974) argued that if a child consumed an adequate amount of calories, it was likely that they would also consume adequate amounts of protein. Coinciding with the 1974 global food (calorie) crisis, McLaren's arguments prompted a much greater emphasis on improving calorie availability. This also suited the emphasis of economists and agronomists on increasing the productivity of calorie-dense staple crops through the Green Revolution. In recent years, however, the 1970s revisionist view has been called into question—there are three strands to this questioning.

The first comes from new work in metabolomics (the study of small molecule chemicals that result from metabolic processes) aimed at understanding cellular growth processes. A relevant example is improvements in understanding mTORs. These are catalytic proteins that signal (or regulate) anabolic processes such as cellular growth and differentiation. One type, mechanistic target of rapamycin complex 1 (mTORC1) regulates growth in chondral plates (i.e., part of the bone where growth takes place) and in skeletal muscle growth. Essential amino acids are needed for the activation of mTORC1 (Semba 2016). These cannot be synthesized from scratch within the human body; they must be obtained via diet; the best sources are animal source foods (ASFs) (meat, poultry, fish, and eggs). Plant sources also contain these, but typically in much lower concentrations. In addition, ASFs are dense in a wide range of micronutrients linked to growth and cognitive development (iron, B12, choline, zinc), and cow's milk

is uniquely rich in calcium and its ability to stimulate the secretion of insulin-like growth factor I (IGF-I), a hormone that stimulates bone and tissue growth (Dror and Allen 2011).

Supporting this view is a smattering of small-scale, somewhat idiosyncratic randomized control trials and observational studies. Walker et al. (1991) provided a high-protein milk-based supplement to stunted children aged 9–24 months in Jamaica, finding that the growth in length was 0.89 cm higher in the treatment group. Likewise, several observational analyses of household surveys show that children from cow-owning households are taller than children whose households do not own cows (Rawlins et al. 2014; Hoddinott, Headey, and Dereje 2015; Choudhury and Headey 2017a) even after controlling for household wealth.[1,2] Tang et al. (2014) conducted a cluster-randomized controlled trial in China that provided a daily 60g-portion of minced pork to a treatment group. The growth in length was 0.26 cm higher in the treatment group relative to the control group who received rice. Iannotti et al. (2017) randomly assigned 6–9 month-old children into treatment that provided one egg per day for a 6-month period and a control that followed a usual diet. The effects were large: length-for-age z score increased by 0.63 SD and stunting prevalence decreased by 47% relative to the control group.

Finally, economic historians have been examining the links between access to ASFs, primarily meat and dairy, and adult stature. Data from 19th century Bavaria show how statures were greater in regions that had higher levels of per capita milk production (Baten and Murray 2000; Baten 2009).[3]

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[1] Still other studies review relationships between ASF intake and growth, but not among pre-school children, and only in a mix of high- and low-income countries (Hoppe, Mølgaard, and Michaelsen 2006; de Beer 2012).

[2] Grasgruber et al. (2016) analyze data on adult male heights from 105 countries, which they link to dietary proxies from the FAO Food Balance Sheets and genetic markers linked to lactose intolerance. These authors show that adult male heights are most highly correlated with animal-sourced protein intake, which is in turn strongly associated with more lactose-tolerant genetic profiles.

[3] The absence of technology to refrigerate inhibited trade meant that local production and consumption of dairy were highly correlated. In the United States, mechanical refrigeration technology started to spread in the late nineteenth century, facilitating market integration of perishable foods such as dairy (Goodwin, Grennes, and Craig 2002). Craig, Goodwin, and Grennes (2004) estimate that the adoption of refrigeration post 1890s United States increased annual dairy consumption and annual protein intake by 1.7 % and 1.25 %, respectively. The

Similarly, per capita cattle holdings are found to be an important predictor of within-country differences in female stature in post-colonial Africa (Moradi and Baten 2005). Takahashi (1984) argues that the post-war improvements in child heights in Japan are strongly linked to the introduction of dairy into the Japanese diet.

The common implication of these different strands is that chronic undernutrition in developing countries may reflect low levels of ASF intake. But the small-scale nature of the few randomized control trials of ASFs, together with the idiosyncratic nature of observational work, gives pause. To the best of our knowledge, there are no studies that systematically assesses patterns of ASF consumption in the critical 6–24-month growth window across countries and regions, whether these consumption patterns are associated with stunting, and what economic drivers underpin these patterns of ASF consumption. This paper attempts to redress these knowledge gaps by posing three objectives.

The first is descriptive. Using an unusually large agglomeration of recent Demographic Health Surveys (DHS), encompassing 130,432 children aged 6–23 months living in 49 low- and middle-income countries, we document complex regional patterns of ASF intake in 24-hour recall data. Second, we use these data to conduct an age-disaggregated multivariate analysis of the associations between children's food consumption patterns and child height in models saturated with a host of relevant control variables. We assess the predicted decline in stunting due to consumption of any ASF, multiple ASFs, specific ASF groups (dairy, eggs, meat/fish), as well as regional variation in ASF-stunting relationships. Third, we explore why ASF consumption is low, but also so variable across countries and regions, even those at similar levels of income. We link DHS data to national level data on "cereal-relative caloric prices" that tell us how expensive a source of calories each ASF is relative to the cheapest staple cereal in each country. Combined, these data can shed light on why consumption of ASFs vary across countries and households. This analysis provides a potential entry point into this issue for agricultural economists because high relative ASF prices imply an important role for agricultural policies—in production, marketing and trade—to improve the accessibility and affordability of ASFs in poorer countries.

Data and Methods

We use multi-country household survey data from phases 5 and 6 of the Demographic Health Surveys (DHS), covering surveys conducted between 2006 and 2014 (ICF International 2015). The DHS are widely used in analyses of child nutrition, including the main dependent variables in our analysis, child stunting, which is defined as a height-for-age Z-score less than 2 standard deviations below the World Health Organization (WHO; 2006) growth standards. Since the mid-2000s (phase 5), the DHS has implemented a highly standardized dietary module in which mothers are asked to recall which of 14 disaggregated food groups their youngest child (0–24 months of age) consumed in the past 24 hours.[4] Table 1 lists these aggregated food groups along with the aggregations we use for our analysis. These data are available for 130,432 children aged 6–23 months from 49 countries in five regions, thus ensuring reasonable region-specific sample sizes (see supplementary online appendix table 1 for a full list of countries): Latin America & Caribbean (7 countries, 29,387 children); Middle East & North Africa (4 countries, 14,445 children); Central, South & South-East Asia (9 countries, 24,721 children); West & Central Africa (16 countries, 37,474 children); Eastern & Southern Africa (13 countries, 24,405 children).

While the large sample sizes and broad geographic coverage of these data are considerable strengths, there are limitations. First, we only know whether a child consumed some amount of these food groups in the past 24 hours. We do not have data on quantities, nor do we know the frequency or duration of consumption. Second, where there are multiple children aged less than 24 months in the household, the DHS only collects dietary data for the youngest child. The youngest children within this age range are not relevant to our analysis since: (*a*) children 0–5 months are (or should be) exclusively

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authors further estimate that a large fraction of the improvement in adult statures in 1890s were due to refrigeration.

[4] We do note one idiosyncrasy: Peruvian DHS do not provide any disaggregated data on flesh foods, with fish and meat/organs aggregated together.

Table 1. Aggregating Food Groups in Phases 5 and 6 of the Demographic Health Surveys

Food Groups Found in DHS Data	Aggregated Food Groups Used in This Analysis	Aggregated Food Groups Used in This Analysis with ASFs Disaggregated
(1) Grains	Starchy staples: (1) Grains, (2) Roots/tuber	Starchy staples: (1) Grains, (2) Roots/tuber
(2) Roots/tubers		
(3) Legumes/nuts	Legumes/nuts	Legumes/nuts
(4) Vitamin A rich fruits	Any fruit: (4) Vitamin A rich fruits; (6) Other fruits	Any fruit: (4) Vitamin A rich fruits; (6) Other fruits
(5) Vitamin A rich vegetables	Any vegetables: (5) Vitamin A rich vegetables; (7) Dark green leafy vegetables; (8) Other vegetables	Any vegetables: (5) Vitamin A rich vegetables; (7) Dark green leafy vegetables; (8) Other vegetables
(6) Other fruits		
(7) Dark green leafy vegetables,		
(8) Other vegetables		
(9) Fresh/powdered cow's milk	Any ASF: (9) Fresh/powdered cow's milk; (10) Infant formula; (11) Eggs; (12) Meat/organs; (13) Fish	Dairy: (9) Fresh/powdered cow's milk; (10) Infant formula;
(10) Infant formula		
(11) Eggs		Eggs
(12) Meat/organs		Meat/fish: (12) Meat/organs; (13) Fish
(13) Fish		
(14) Fortified infant cereals		

breastfed; and (*b*) one would not expect to see instantaneous growth benefits from a recent introduction of complementary foods (e.g., in the 6–11-month range). Instead, the benefits of an improved diet would be expected to accumulate throughout the first two years of life, consistent with the growth-faltering patterns observed in Victora et al. (2010). Indeed, one recent analysis strongly suggests that analyses of the determinants of child growth should typically focus on children who have completed the first two years of life (Alderman and Headey 2018). For this reason, we focus on children aged 6–23 months, but also disaggregate within this age group to focus on 6–11, 12–17 and 18–23-month age brackets. Consistent with Alderman and Headey (2018), our expectation is that the associations between dietary indicators and stunting is strongest for the 18–23-month group.

A bivariate analysis of consumption of ASFs and stunting carries with it the obvious risks associated with the presence of confounding factors. Many factors that might determine ASF consumption might also affect nutritional status through other channels. For this reason, we estimate linear probability models that include the full set of controls listed in table 2—mostly drawn from (Danaei et al. 2016).[5] In addition to controlling for child age (through age-in-month dummies) and sex, our selection of control variables is informed by the notion of a nutrition production function (Behrman and Deolalikar 1988) including: nutrients (the food groups described above); illness (diarrhea); maternal knowledge of good nutrition (maternal education); the health environment (the sanitation and water variables); and genetic endowments (maternal height measured in cm).[6,7] We control for whether the mother was a teenager (<20 years) when the child was born, which captures aspects of both maternal knowledge

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[5] Our results are robust to using a probit model instead of linear probability model.

[6] Diarrhea can also be considered as an outcome variable in the sense that ASF consumption could increase or decrease diarrhea risk among young children. However, our results are robust to omitting this variable from the model.

[7] Assets (or incomes) do not typically directly enter the nutrition production function as they are thought to influence nutrition outcomes indirectly through various inputs. Still, a consistent empirical finding in the literature is that ASFs have high-income elasticities (e.g., Pinstrup-Andersen and Caicedo 1978; Colen et al. 2018), raising a concern that our ASF coefficients are picking up wealth effects. Our main specification does not include household assets, but our results are robust to their inclusion (see table S3 in the supplementary online appendix).

Table 2. Summary Statistics for Key Variables

Variable	Obs.	Mean	Std. Dev.
Stunting (0/1)	130,432	0.32	0.46
Grain/root/tuber (0/1)	130,432	0.76	0.43
Legume/nut (0/1)	130,432	0.25	0.43
Fruits (0/1)	130,432	0.36	0.48
Vegetables (0/1)	130,432	0.32	0.47
ASFs (0/1)	130,432	0.62	0.49
Dairy (0/1)	130,432	0.35	0.48
Eggs (0/1)	130,432	0.22	0.42
Meat/fish (0/1)	130,432	0.38	0.49
Red/white meat (0/1)	130,432	0.24	0.43
Fish (0/1)*	117,626	0.20	0.40
Fortified infant cereals (0/1)	130,432	0.10	0.30
Currently breastfed (0/1)	130,432	0.77	0.42
Infant formula (0/1)	130,432	0.10	0.30
No food yesterday (0/1)	130,432	0.12	0.33
Diarrhea (0/1)	130,315	0.23	0.42
Medical facility birth (0/1)	130,432	0.61	0.49
Improved latrine (0/1)	130,432	0.30	0.46
Unimproved toilet (0/1)	130,432	0.42	0.49
Improved water (0/1)	130,432	0.63	0.48
Teenage mother (0/1)	130,432	0.18	0.39
Mother's height (cm)	130,432	155.8	7.15
Woman 9+ yrs education (0/1)	130,432	0.33	0.47
Partner 9+ yrs education (0/1)	130,432	0.38	0.48
Partner absent (0/1)	130,432	0.11	0.31
Child is boy (0/1)	130,432	0.51	0.50
Age (months)	130,432	14.2	5.13
Rural (0/1)	130,432	0.65	0.48

Note: These are DHS data from 49 countries listed in supplementary online appendix table 1. Asterisk * indicates fish consumption data are not available for Peru.

of child care and nutrition practices as well as child endowments. We include survey dummies, meaning that the regression coefficients represent within-survey associations with stunting. We further control for subnational fixed effects (states, provinces, et cetera) and whether the child resides in a rural area. The inclusion of geographical fixed effects allows us to capture, to a certain extent, regional patterns in food access, prices, incomes, health, and the health environment. While these control variables capture some aspects of confounding factors, it would be a mistake to assume that they capture all inputs into the nutrition production function and for this reason we refer to our results as associations, not causal estimates. Our regression results are not population-weighted, but the coefficients do reflect implicit weights based on sample size and on within-survey variation in stunting and dietary variables.

In the final part of the analysis, we supplement DHS data with national level data on cereal-relative calorie prices (CCPs) from Headey et al. (2017). The underlying price data pertain to nationally averaged prices of 200 standardized food products collected by national statistical agencies for 177 countries under the auspices of The International Comparison Program (ICP) coordinated by the World Bank. These weight-based prices were then converted to prices per calorie. Specific foods were then allocated into groups (see table 3), and in each country the cheapest staple cereal was selected as a numeraire. CCPs were then constructed by taking the ratio of the cheapest food in each group to the cheapest staple cereal in a country. As an example, the CCP for eggs in Bangladesh is the ratio of the price of 1 calorie of an egg relative to 1 calorie of rice. Table 3 indicates that most ASF categories involve good coverage of a range of specific food items, although apart from tilapia, there is insufficient coverage of local varieties of freshwater fish. Coverage of fresh and processed dairy products is good (6 products), as is eggs (medium and large).

Table 3. Classification of Cereals and Specific ASF Products in the ICP 2011 Data

Food Group	Number of products	Specific Products Used to Construct Minimum Price
Cereals	13	Rice (5 types), bread products (5 types), maize flour, maize, tortilla
Cow's milk, fresh	2	Pasteurized fresh milk, unskimmed or low-fat
Cow's milk, long-life	3	Condensed milk, powdered milk, UHT
Meat, fresh	20	Whole chicken (2 types), chicken breast, chicken leg; Beef/veal (7 varieties), Lamb/mutton (4 varieties), Pork (4 varieties), Goat (1 variety); all unprocessed.
Chicken eggs, fresh	2	Large brown eggs, medium brown eggs
Fish, fresh	5	Fresh Carp, Mackerel or Tilapia; canned Sardines or canned Tuna

Source: Headey et al. (2017).

We use these national-level price data in linear probability regressions where consumption of individual ASFs is modelled as a function of child and household characteristics from the DHS—including important predictors of ASF consumption such as household wealth and parental education—and national level prices (CCPs). The inclusion of time-invariant prices for 2011 means that these regressions necessarily omit survey/country dummies, but we include a series of additional national-level control variables that might influence ASF prices and simultaneously determine ASF consumption patterns through other mechanisms. These variables are sourced from the World Bank and include GDP per capita, cereal yields, and a conflict dummy variable.

Dietary Patterns among Young Children

Table 4 reports nutrition and dietary indicators for children 6–23 months. Stunting rates are high at 31.5%. The regional

Table 4. Stunting and Dietary Patterns by Region and Child's Age

	All Children (6–23 mo)	Latin America & Caribbean (6–23 mo)	Middle East & North Africa (6–23 mo)	South, Central & SE Asia (6–23 mo)	West & Central Africa (6–23 mo)	Eastern & Southern Africa (6–23 mo)	All Children 6–11 mo	All Children 12–17 mo	All Children 18–23 mo
Stunted	31.5%	22.5%	25.9%	37.7%	32.9%	37.4%	21.6%	32.8%	41.3%
Child consumed:									
Any ASF	62.0%	82.9%	75.5%	56.8%	52.0%	49.3%	50.7%	66.4%	69.8%
1 ASF only	35.8%	27.8%	38.2%	43.7%	35.4%	36.4%	34.6%	37.0%	35.7%
2 ASFs	20.3%	36.2%	30.3%	13.8%	13.5%	12.0%	15.0%	22.2%	24.0%
3 ASFs	8.5%	20.6%	11.0%	4.3%	4.4%	3.2%	4.8%	9.4%	11.8%
Dairy	35.4%	52.1%	64.0%	37.7%	20.6%	18.6%	29.2%	37.4%	40.0%
Eggs	22.4%	45.3%	30.2%	15.5%	12.1%	13.1%	16.6%	24.1%	27.0%
Meat/fish *	37.9%	55.9%	30.1%	22.7%	39.4%	33.7%	26.4%	41.8%	46.3%
Red/white meat	24.3%	51.3%	23.6%	13.2%	15.4%	17.4%	16.5%	26.8%	30.4%
Fish	19.6%	N/A	7.6%	12.6%	31.3%	21.0%	13.7%	21.8%	24.0%

Note: Data pertain to children 6–23 months of age from DHS surveys from 49 countries. Asterisk * indicates that fish consumption data are not available for Peru.

disaggregation shows that stunting is much higher in the two sub-Saharan African regions and Asia—where roughly one-third of children in this age range are stunted—than in the two predominantly middle-income regions. Consumption of ASFs follows a similar pattern. While 61.8% of children consumed at least one ASF the previous day, this masks considerable heterogeneity across regions. Latin America and the Caribbean region, with the highest proportion of children consuming an ASF (82.9%), has the lowest prevalence of stunting (22.35%), while the Eastern and Southern Africa region has the lowest proportion of children consuming an ASF (49.3%) and the highest prevalence of stunting (37.4%). Table 4 also shows that consumption rates among different ASFs are broadly similar in the Latin America and Caribbean region, with roughly half of children consuming dairy, meat/fish or eggs in the past 24 hours. Moreover, 36.2% of children in this region consumed two ASFs in the past 24 hours, while 20.6% consumed all three ASFs. In most other regions, one ASF tends to dominate. Dairy dominated in the Middle East and North Africa region (64.0%), although a substantial share of children consumes multiple ASFs there. Dairy also dominates in the South, Central and South-East Asia region (37.7%), although in some countries fish is more important (Bangladesh). Fish is also dominant in the West and Central Africa region (31.3%), but no particular ASF is dominant in the Eastern and Southern Africa region. It is also notable that relatively few children in these poorer regions consume multiple ASFs (<20%).

To contextualize age-specific patterns of stunting and consumption of ASFs, figure 1 plots stunting against child age for 49 countries. Just after birth, roughly 18% of the sample is stunted, but this changes little for the first few months of life when most infants are predominantly breastfed. From 4–5 months onwards, stunting rates increase precipitously until about 20 months of age where they level off at just over 40%. Regional data show similar patterns of accelerated growth faltering (supplementary online appendix figure 1). Figure 2 plots consumption of any ASF and some specific ASFs by child age. Dairy is the most commonly consumed ASF in this sample. While the Food and Agriculture Organisation of the United Nations (FAO) recommends dairy

products to be introduced only at 12 months because of potentially adverse side effects on fragile infant digestive systems (FAO 2013), in this sample about 20% of children 6 months of age consumed dairy products on the previous day. This rises to 40% by 18 months. The consumption of eggs, meat, and fish are all less common than dairy and are characterized by similar levels of consumption at all ages.

Associations between Stunting and Animal Sourced Foods

Our parametric results are reported in table 5. The control variables provided above (including the sub-national fixed effects) are included in these regressions but their coefficients are not reported (see supplementary online appendix table 2 for full results). In the first column, we look at the association between the consumption of any ASF and stunting. The coefficient is statistically significant and negative, and its magnitude implies that, on average, intake of an ASF is associated a 2.3-percentage point reduction in stunting rate. Considering the overall stunting rate of 31.5% in this age-range, a 2.3-percentage points translates into a 7.2% reduction in stunting. When we disaggregate the data by child age (columns 2, 3, and 4), we see the expected result that the associations tend to strengthen for older age brackets. For children aged 18–23 months—our preferred sample—consumption of an ASF the previous day is associated with a four-percentage point reduction in the likelihood of being stunted. Since the stunting rate among children in this age range is 41.3% (see table 4), this translates into 9.7% reduction in stunting. Note that this association is larger than that observed for other non-staple foods. This includes legumes—an important alternative source of protein, especially in low-income countries (Messina 1999). Moreover, the ASF and legume coefficients are statistically different from zero.[8] We also note that the coefficient on fruit is significant

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[8] We can reject the null hypothesis that the coefficients on legumes and ASFs are equal. Consistent with this, adding consumption of legumes to our ASF variable (thus creating a variable capturing the consumption of proteins from animal or plant sources) yields a coefficient slightly smaller than the coefficient on ASFs. Results are available upon request.
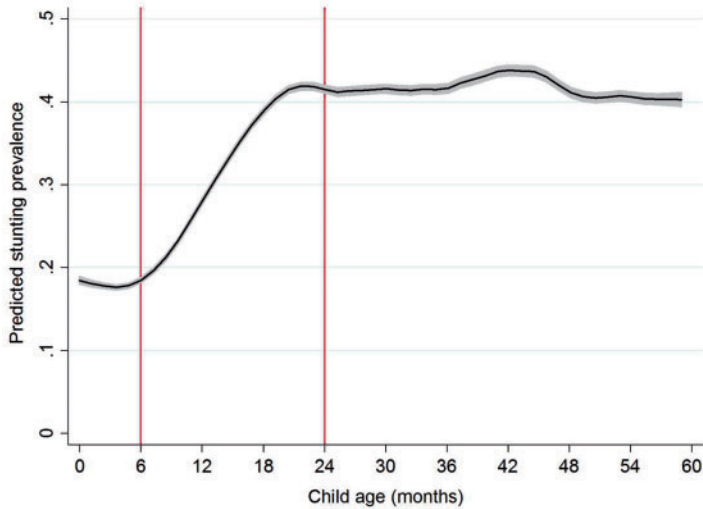
Figure 1. Stunting prevalence by child age for children from 49 countries

Note: These are local polynomial plots of stunting against child age, with 90% confidence intervals, for 296,370 children aged 0–59 months
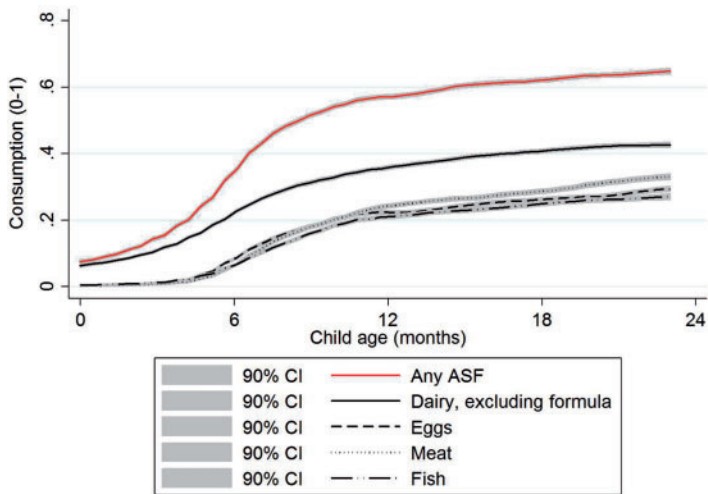

Figure 2. Consumption of any ASF and specific ASFs, by child age

Note: These are local polynomial plots of ASF consumption indicators against child age, with 90% confidence intervals, for 147,521 children aged 0–23 months

and negative in all samples, although it is again statistically smaller than the coefficient on ASFs in the 18–23-month sample.[9]

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[9] The significant negative coefficient on fruit consumption is biologically plausible. Fruits are soft and highly palatable for young children and require very little preparation time, implying that fruit consumption might be associated with higher calorie intake. Fruits are also rich in a wide array of micronutrients that are beneficial for immune system strengthening. However, while fruit consumption has an association with stunting, the coefficient tends to be smaller than the ASF one (see table 5) and, unlike ASF, is not consistent across regions (see table 6).

In table 6, we re-run column 4 in table 5 on region-disaggregated data. The coefficient on the ASF consumption variable remains negative in all sub-samples and is statistically significant at the 5% level in four out five regions. Only in the Middle East & North Africa (MENA) region is the association between ASF intake and stunting not statistically significant. Elsewhere, consumption of at least one ASF is associated with a 2–9 percentage point reduction in the likelihood of being stunted, with the strongest association

Table 5. ASFs Are Negatively Associated with Stunting, Especially in the 18–23-month Age Group

Sample:	(1) 6–23 Month Children	(2) 6–11 Month Children	(3) 12–17 Month Children	(4) 18–23 Month Children
Any ASF	−0.023***	−0.016***	−0.011**	−0.040***
	(0.003)	(0.005)	(0.006)	(0.006)
Grains/roots/tubers	−0.015***	−0.023***	−0.001	−0.013
	(0.004)	(0.006)	(0.008)	(0.009)
Legumes/nuts	−0.006**	−0.007	−0.006	−0.003
	(0.003)	(0.005)	(0.005)	(0.006)
Any fruit	−0.019***	−0.015***	−0.014***	−0.018***
	(0.003)	(0.005)	(0.005)	(0.005)
Any vegetables	0.003	−0.006	−0.001	0.004
	(0.003)	(0.005)	(0.005)	(0.005)
Child and household level controls?	Yes	Yes	Yes	Yes
Rural dummy?	Yes	Yes	Yes	Yes
Survey dummies?	Yes	Yes	Yes	Yes
Sub-national fixed effects?	Yes	Yes	Yes	Yes
Coefficient on ASF is statistically different to the coefficients on other food groups?	Yes (except fruit)	No	No	Yes
R-squared	0.149	0.104	0.141	0.167
Observations	130,315	45,316	45,026	39,973

Note: Unit of observation is a child and the dependent variable obtains a value 1 if the child is stunted, and zero otherwise. Standard errors clustered at the DHS cluster level. Child and household level controls include: Child had a diarrhea (0/1), Medical facility birth (0/1), Improved latrine (0/1), Unimproved toilet (0/1), Improved water (0/1), Teenage mother (0/1), Mother's height (cm), Woman 9+ yrs education (0/1), Partner 9+ yrs education (0/1), Partner absent (0/1), child is boy (0/1), and child's age (age-in-months dummies). Also included are survey dummies, subnational fixed effects (states, provinces, et cetera) and whether the child resides in a rural area. Statistical significance denoted as ***= $p < 0.01$, **= $p < 0.05$, and *= $p < 0.1$.

Table 6. ASF Consumption Is Associated with Reduced Risks of Stunting in Children 18–23 Months of Age in All Regions Except the Middle East and North Africa

Sample:	(1) Latin America & Caribbean	(2) Middle East & North Africa	(3) South, Central & SE Asia	(4) West & Central Africa	(5) Eastern & Southern Africa
Any ASF	−0.088***	−0.018	−0.042***	−0.022**	−0.045***
	(0.017)	(0.026)	(0.013)	(0.011)	(0.013)
Grains/roots/tubers	−0.039*	0.046*	−0.015	−0.024	−0.004
	(0.023)	(0.027)	(0.022)	(0.017)	(0.018)
Legumes/nuts	0.000	−0.010	−0.032**	0.012	−0.007
	(0.009)	(0.017)	(0.014)	(0.012)	(0.014)
Any fruit	−0.013	−0.026	−0.028**	−0.005	−0.031**
	(0.010)	(0.017)	(0.012)	(0.011)	(0.013)
Any vegetables	0.001	0.039**	−0.002	0.002	0.004
	(0.010)	(0.018)	(0.012)	(0.010)	(0.013)
Other food groups?	Yes	Yes	Yes	Yes	Yes
Child and household level controls?	Yes	Yes	Yes	Yes	Yes
Rural dummy?	Yes	Yes	Yes	Yes	Yes
Survey dummies?	Yes	Yes	Yes	Yes	Yes
Sub-national fixed effects?	Yes	Yes	Yes	Yes	Yes
R-squared	0.223	0.138	0.171	0.123	0.104
Observations	9,507	3,857	7,831	10,662	7,480

Note: Unit of observation is a child, 18–23 months and the dependent variable obtains a value 1 if the child is stunted, and zero otherwise. Standard errors clustered at the DHS cluster level. Controls are those listed in table 5. Statistical significance denoted as ***= $p < 0.01$, **= $p < 0.05$, and *= $p < 0.1$.

Table 7. Consuming More than 1 Type of ASFs is Associated with a Significantly Lower Risk of Stunting in the 18–23-Month Age Group

	(1) 6–23 Months	(2) 6–11 Months	(3) 12–17 Months	(4) 18–23 Months
1 ASF	−0.018***	−0.017***	−0.010*	−0.037***
	(0.003)	(0.005)	(0.006)	(0.007)
2 ASFs	−0.034***	−0.021***	−0.009	−0.057***
	(0.004)	(0.007)	(0.007)	(0.008)
3 ASFs	−0.045***	−0.009	−0.014	−0.061***
	(0.005)	(0.010)	(0.009)	(0.010)
Other food groups?	Yes	Yes	Yes	Yes
Child and household level controls?	Yes	Yes	Yes	Yes
Rural dummy?	Yes	Yes	Yes	Yes
Survey dummies?	Yes	Yes	Yes	Yes
Sub-national fixed effects?	Yes	Yes	Yes	Yes
P-value of H0: β(1 ASF) = β(2 ASFs)	0.000***	0.416	0.852	0.002***
P-value of H0: β(1 ASF) = β(3 ASFs)	0.000***	0.422	0.593	0.003***
P-value of H0: β(2 ASF) = β(3 ASFs)	0.024**	0.182	0.512	0.762
R-squared	0.150	0.105	0.142	0.169
Observations	130,315	45,316	45,026	39,973

Note: Unit of observation is a child and the dependent variable obtains a value 1 if the child is stunted, and zero otherwise. Standard errors clustered at the DHS cluster level. Controls are those listed in table 5. Statistical significance denoted at ***= $p < 0.01$, **= $p < 0.05$, and *= $p < 0.1$.

pertaining to the Latin America and Caribbean sample, where ASF consumption is both high and diverse (table 4).

Tables 7 and 8 extend this core finding in two ways. Table 7 assesses whether the number of different ASFs consumed is associated with stunting. Biologically, one would expect diversity in ASF consumption to yield larger growth benefits because different ASFs contain different growth-stimulating nutrients. Dairy, for example, is rich in calcium and contains a growth stimulating hormone (IGF-1) but is bereft of iron, whereas meat, fish, and eggs are relatively rich in iron but low in calcium. And as we saw in table 4, there are substantial numbers of children who consume multiple ASFs (over 40% in Latin America and MENA, and less than 20% in other regions). The results in table 7 suggest there are additional benefits to consuming multiple ASFs. In the 6–23-month sample, the implied reduction in stunting to one ASF is just 1.8 points, but this rises to 3.4 points and 4.5 points for 2 ASFs and 3 ASFs, respectively, and all three coefficients are statistically different from one another. The results are much weaker in the 6–11-month and 12–17-month sample, but substantially stronger in the preferred 18–23-month sample. In that sample consumption of one ASF is associated with stunting being reduced by 3.7-percentage points, but

consuming one additional ASF is associated with a *further* 2-percentage point reduction ($p < 0.01$). Consuming three ASFs also implies a large reduction in stunting (6.1 points), but the implied difference between 2 ASFs and 3 ASFs is not statistically significant.

Table 8 disaggregates by type of ASF; all ASF types are associated with lower stunting among children aged 18–23 months, although the coefficient on dairy is significantly larger than the coefficients on eggs and meat/fish. The results in table 8 are consistent with table 7 insofar as the implied benefits of different ASFs are additive. For example, among children aged 18–23 months, the implied reduction in stunting from consuming dairy, eggs, and meat/fish is a 6.6-point reduction (3.4 from dairy, 1.3 points from eggs, and 2.1 points from meat/fish).

supplementary online appendix table 3 also adds a potentially important confounding factor to the model (household wealth) measured via a principal components analysis of household assets (Filmer and Pritchett 2001). Wealth is likely an important determinant of ASF consumption but could also independently influence stunting. However, the results from table 5 are robust to the inclusion of wealth terciles, even though the coefficient on middle- and upper-wealth terciles are themselves highly significant. In

Table 8. All ASF Types Are Associated with Lower Stunting among Children 18–23 months, although Dairy Has the Strongest Association

	(1) 6–23 months	(2) 6–11 months	(3) 12–17 months	(4) 18–23 months
Dairy	−0.020***	−0.008	−0.011*	−0.034***
	(0.003)	(0.005)	(0.006)	(0.006)
Eggs	−0.011***	−0.001	0.001	−0.013**
	(0.003)	(0.005)	(0.005)	(0.006)
Meat/Fish	−0.017***	−0.014***	−0.005	−0.021***
	(0.003)	(0.005)	(0.005)	(0.005)
Other food groups?	yes	yes	Yes	yes
Child and household level controls?	yes	yes	Yes	yes
Rural dummy?	yes	yes	Yes	yes
Survey dummies?	yes	yes	Yes	yes
Sub-national fixed effects?	yes	yes	Yes	yes
P-value of H0: β(Dairy) > β(Eggs)	0.034**	0.184	0.076*	0.008***
P-value of H0: β(Meat) > β(Eggs)	0.092*	0.046**	0.199	0.152
P-value of H0: β(Dairy) > β(Meat)	0.266	0.202	0.225	0.056*
R-squared	0.150	0.105	0.142	0.169
Observations	130,315	45,316	45,026	39,973

Note: Unit of observation is a child and the dependent variable obtains a value 1 if the child is stunted, and zero otherwise. Standard errors clustered at the DHS cluster level. Controls are those listed in table 5. Statistical significance denoted at ***= $p < 0.01$, **= $p < 0.05$, and *= $p < 0.1$.

the 18–23-month sample, for example, the coefficient on ASF drops from 0.040 to 0.038 and remains statistically significant. Thus, there is little indication that the estimated benefits of ASFs simply represent the greater economic status of ASF-consuming households.

Constraints to ASF Consumption in Developing Countries

The evidence above suggests significant nutritional benefits from consuming ASFs, and yet ASF consumption in poorer countries is generally very low. Why is this? One perceived barrier is a lack of nutritional knowledge. Many nutritional programs have attempted to improve nutritional knowledge, albeit it with mixed success and substantive concerns on sustainability (Dewey and Adu-Afarwuah 2008; Menon et al. 2015). Consistent with knowledge constraints, parental education has been strongly linked to nutrition outcomes and dietary diversity even when applying methods to reduce endogeneity bias (Alderman and Headey 2017). Gender bias and low levels of maternal empowerment are also widely-cited constraints (Jayachandran and Pandi 2017), as are food taboos (Pachón et al. 2007; Zerfu, Umeta, and Baye 2016). Additionally, many studies show that

consumers diversify away from starchy staple foods as incomes rise as per Bennett's law (Choudhury and Headey 2017b), opting for more expensive sources of calories as incomes rise (Subramanian and Deaton 1996), including strong demand for ASFs (Colen et al. 2018). If incomes constrain ASF consumption, this suggests they may be a very expensive source of calories in low-income countries. Certainly, many ASFs are imperfectly tradable, especially in environments with underdeveloped value chains (e.g., poor transport, lack of cold storage, and low levels of processing). Highly perishable foods also have associated food safety risks, with semi-commercialized dairy systems being a notable example in both contemporary developing economies (Gizachew et al. 2016) and early twentieth century industrialized societies (Gordon 2016). In turn, this draws attention to the price of ASFs as a factor constraining children's consumption of these foods.

Table 9 reports data on the price of ASFs and other foods relative to the price to a country-specific numeraire, the cheapest staple cereal (i.e., rice, wheat, and maize products). For example, the value 6.1 for fish in Eastern & Southern Africa tells us that it costs 6.1 times more to consume a calorie from a fish product than it does a calorie from a staple cereal. Across all regions, roots and tubers are very cheap sources of calories.

Table 9. Cereal-relative Calorie Price Ratios for Various Foods, by Region

		Vegetal sourced food prices				
	Roots & Tubers	Vitamin A-rich Fruit and Veg.	Dark Green Leafy Veg.	Other Veg.	Other Fruit	Legumes
High income	1.6	3.0	9.0	3.3	1.7	1.2
Latin America & Caribbean	1.2	1.9	5.6	6.5	1.3	2.2
Middle East & North Africa	2.1	2.5	6.1	5.3	3.3	2.1
South, Central & South-East Asia	1.5	1.9	6.2	6.0	3.1	2.0
Western & Central Africa	1.0	2.3	11.5	11.6	3.1	NA
Eastern & Southern Africa	1.7	3.1	7.3	11.4	3.2	NA
		Animal sourced foods & fortified baby cereal prices				
	Cow's milk, fresh	Cow's milk, processed	Chicken eggs	Meat	Fish	Fortified baby cereal
High income	3.2	2.2	3.0	2.0	4.3	5.0
Latin America & Caribbean	3.9	3.0	4.9	3.2	3.4	9.6
Middle East & North Africa	10.1	3.1	6.1	6.2	6.0	16.1
South, Central & South-East Asia	7.8	3.8	6.2	6.5	5.3	16.4
Western & Central Africa	16.5	4.0	9.9	5.3	5.0	23.4
Eastern & Southern Africa	13.9	5.8	9.1	5.6	6.1	18.6

Note: Caloric prices are the ratio of the price of 1 calorie of a given food (e.g., eggs) relative to 1 calorie of the cheapest staple cereal in each country (e.g., rice, wheat, and maize products). See Headey et al. (2017) for details. NA refers to not available. ICP data did include some legume prices for sub-Saharan Africa, but not widely consumed local varieties.

Strikingly, vitamin-A rich fruits and vegetables and "other fruit" are also relatively affordable, partly because many such fruits are highly suitable to tropical conditions, and because some (e.g., mangos, papayas, bananas) are relatively easy to store and transport. By contrast, vegetables, which are highly perishable and low in calorie density, are an expensive source of calories. Legumes, which are reasonably high in lower-quality protein, are an affordable source of calories in most regions, but less so in Africa.

Price ratios of ASFs, however, reveal striking differences across income levels and regions. Both perishable fresh milk and highly storable processed milk are relatively cheap sources of calories in high-income countries but also in Latin America and the Caribbean. In North Africa and Middle East region, processed milk is very cheap, but fresh milk is very expensive. It is notable that in both these middle-income regions,

consumption of dairy products among infants and young children is widespread, with over half consuming dairy in the past 24 hours (table 4). By contrast, fresh milk is moderately expensive in South, Central and South-East Asia (though relatively cheap in India, where dairy consumption is high), and extremely expensive in sub-Saharan Africa. In Western and Central Africa, for example, fresh milk is 16.5 times as expensive as the cheapest cereals. Processed milk is highly storable, so it is of little surprise that it is more affordable in all regions. Despite this, it would appear that processed milk is not widely consumed in these regions.

Price variation for eggs is even more striking. Eggs are a very cheap source of calories and protein in high-income countries (Iannotti et al. 2014). Yet in the Middle East & North Africa region, they are at least 6 times as expensive as staple cereals, and in Africa they are 9–10 times as expensive.

Table 10. Linear Probability Model Regressions of Consumption of ASFs by Children aged 6-23 months as a Function of Calorie Price Ratios, and Various Child-, Household-, Community-, and National-level Characteristics

	(1) Dairy consumption	(2) Egg consumption	(3) Meat consumption	(4) Fish consumption
Log own price[d]	−0.103***	−0.153***	−0.066***	−0.052***
	(0.005)	(0.006)	(0.005)	(0.004)
Log cereal yields[d]	0.066***	0.015***	−0.081***	−0.064***
	(0.005)	(0.004)	(0.004)	(0.005)
Log GDP per capita[d]	0.075***	−0.029***	0.065***	−0.084***
	(0.004)	(0.004)	(0.004)	(0.005)
Log urbanization rate[d]	−0.002	0.204***	−0.062***	0.114***
	(0.007)	(0.006)	(0.007)	(0.009)
Conflict dummy[d]	0.008	−0.070***	−0.053***	0.041***
	(0.005)	(0.004)	(0.004)	(0.004)
Wealth, middle tercile[b]	0.063***	0.053***	0.024***	0.001
	(0.004)	(0.003)	(0.003)	(0.004)
Wealth, upper tercile[b]	0.162***	0.077***	0.066***	−0.040***
	(0.006)	(0.005)	(0.005)	(0.006)
Mother 9+ yrs of school[b]	0.030***	0.032***	0.044***	0.005
	(0.004)	(0.004)	(0.004)	(0.004)
Father 9+ yrs of school[b]	0.009**	0.004	0.012***	0.023***
	(0.004)	(0.003)	(0.003)	(0.004)
Open defecation, village[c]	−0.019***	−0.061***	−0.042***	−0.010*
	(0.006)	(0.004)	(0.004)	(0.006)
Unimproved water, village[c]	−0.049***	−0.028***	−0.012***	+0.028***
	(0.006)	(0.004)	(0.004)	(0.005)
Women's autonomy[b]	0.018***	0.012***	−0.005	−0.013***
	(0.004)	(0.004)	(0.004)	(0.004)
Currently breastfed[a]	−0.078***	−0.008**	−0.050***	−0.013***
	(0.004)	(0.004)	(0.004)	(0.004)
Rural[c]	0.000	0.008**	−0.022***	−0.027***
	(0.004)	(0.004)	(0.004)	(0.004)
Father absent[b]	0.055***	−0.033***	−0.039***	0.016***
	(0.007)	(0.005)	(0.005)	(0.006)
Hospital/clinic access[b]	0.020***	0.034***	0.012***	0.046***
	(0.004)	(0.003)	(0.003)	(0.004)
R-squared	0.177	0.146	0.104	0.115
Observations	98,840	100,991	91,793	89,896

Note: Unit of observation is a child and the dependent variable obtains a value 1 if the child consumed from the food group, and zero otherwise. Asterisks indicate the following: ***= $p < 0.01$, **= $p < 0.05$, and *= $p < 0.1$. Superscript a indicates child-level indicators; b=household-level indicators; c= community/cluster-level indicators; d= national-level indicators. Regressions also control for short birth interval, number of children, teenage motherhood, child gender. These coefficients had small and often insignificant coefficients.

This provides *prima facie* evidence that the highly perishable nature of eggs and the low productivity of egg production in lower income countries would appear to account for the low levels of egg consumption observed earlier.

The price story on flesh foods is quite different. Both red/white meat and fish are relatively tradable, either because of the scope to trade live animals, or the ability to freeze, dry, smoke, or salt flesh foods. Meat and fish are again notably cheap in high-income countries and in Latin America and the

Caribbean, but also—compared to other ASFs—relatively affordable in sub-Saharan Africa where meat/fish calories are just 5–6 times as expensive as staple cereals. Notably, fortified baby cereals—a potential substitute for ASFs—are extremely expensive in all regions except high-income countries and Latin America and the Caribbean (see Masters, Nene, and Bell 2017 for a more detailed anlaysis).

Table 10 reports linear probability models explaining children's consumption of four different ASFs. Own prices are always

significantly and negatively associated with consumption of each specific ASF. Dairy and egg consumption are especially strongly associated with their relative prices. In the case of dairy, a doubling of the price ratio for fresh milk—for example, the difference between dairy prices in the United States and India—predicts a reduction in dairy consumption of around 10 percentage points. Considering that 35% of the children in our sample consumed dairy (see table 4), this translates into a 29% drop in dairy consumption prevalence. The association for eggs is even stronger, suggesting that the very high prices of eggs in most regions (table 9) provides a strong explanation of why egg consumption is not common among infants and young children in poorer countries. Meat and fish consumption share somewhat more modest associations with their own price ratios. In the case of fish this may be the result of some attenuation bias, as the ICP only measures a few fish varieties relevant to lower-income countries.

Amongst other national factors there are some interesting associations. Dairy and meat consumption have strong associations with GDP per capita, but in the case of dairy there is also an association with household-level wealth that is much stronger than the corresponding associations for other ASFs. Strikingly, fish consumption is negatively associated with GDP per capita and with household wealth. The negative association with national GDP per capita could partly reflect high levels of consumption in much of sub-Saharan Africa, as well as countries like Cambodia and Bangladesh, but the negative association with wealth likely reflect the fact that in many populations, fish is considered an inferior good relative to red/white meat. Also notable is that the national urbanization rate is very strongly associated with egg and fish consumption, but negatively associated with meat consumption. These results might indicate that more commercialized large-scale low-cost poultry production systems tend to emerge when large urban agglomerations give rise to concentrated centers of demand (Narrod, Pray, and Tiongco 2008).

Conclusions

Despite plausible biological mechanisms linking ASF intake to child growth, there is a surprising dearth of evidence on this relationship in developing countries, and little previous work has systematically documented patterns of ASF consumption among young children or attempted to explain why these patterns exist.

In this paper we document that ASF consumption among young children is relatively low in sub-Saharan Africa and most of Asia, but is also characterized by some distinctive patterns. Most notable are: (*a*) low levels of dairy consumption in most lowland areas of Africa and much of Asia (Bangladesh, Cambodia), but relatively high levels of fish consumption; (*b*) low levels of egg and red/white meat consumption in Africa and Asia; (*c*) low levels of multiple ASF consumption in Africa and Asia (<20%). We show evidence of strong associations between ASF consumption and child growth, particularly consumption of multiple ASFs and of dairy. Finally, we show that high relative prices of ASF calories are a critical constraint restricting consumption of these foods, especially for highly perishable products such as fresh milk and eggs. While our econometric models are saturated with a wide array of controls and are robust to the inclusion of household wealth, we emphasize that these are associations, not causal relations. That being said, there is also an important reason to suspect that we may be underestimating the association between ASF consumption on stunting: the 24-hour recall is likely to be an imperfect proxy for usual diets (i.e., within-person error) leading to an attenuation bias (Thorne-Lyman, Spiegelman, and Fawzi 2014). This may also be more problematic for some ASFs than others since some (e.g., dairy) may be consumed in larger quantities and more frequently than others (e.g., flesh foods, eggs). All this points to the need for new studies that can illustrate the causal links between quantities of ASF consumption and child nutrition.

For the agriculture and nutrition communities, these findings are of clear importance. Nutritionists have long promoted interventions designed to improve nutritional knowledge on feeding practices, and/or to increase homestead production of ASFs (Leroy and Frongillo 2007; Dewey and Adu-Afarwuah 2008). The extremely high prices of ASFs suggests these interventions could have limited impacts, however. One reason is that high ASF prices provide strong incentives for producers to sell ASFs rather than feed them to their own children. Behavioral change

interventions are used to encourage house-
holds to at least partially resist the financial
rewards of selling ASFs, but doing so is costly
and potentially unsustainable, and will still
fail to increase ASF consumption among
non-producers. Potentially a more cost-
effective and sustainable strategy is to em-
ploy larger-scale investments in the livestock
and fisheries sector and its associated value
chains, and/or appropriate trade policies, to
reduce the prices of ASFs for all consumers.

In the case of eggs—a highly non-tradable
product—investments in domestic production
are clearly crucial. However, egg production
is characterized by huge economies of scale
(Narrod, Pray, and Tiongco 2008), suggesting
that investments in village production sys-
tems are unlikely to be economically effi-
cient. Moreover, a growing body of research
also suggests scavenging poultry systems are
hazardous to the health of young children
(Ngure et al. 2013; Headey and Hirvonen
2016). For dairy, the issue is much more com-
plex since dairy powder is highly tradable but
not obviously a close substitute for fresh
milk, nor highly desirable in contexts where
water quality is a major concern. Many popu-
lations in tropical regions also have little tra-
dition of consuming milk, and adults face
lactose intolerance issues, suggesting there
may be significant cultural issues to be over-
come (FAO 2008). Meat and fish are also
complex sectors characterized by both inten-
sive and extensive production modalities and
some degree of tradability. The importance
of fish in many African and Asian diets—
even those of young children—makes it a
particularly interesting sector for future re-
search and investment. One concern is that
extensive systems are facing major over-
fishing problems in Africa especially, al-
though more sustainable fish farming systems
have experienced explosive growth in much
of Asia and parts of Africa and may offer a
pathway to expanding fish consumption
(Béné et al. 2015).

While ASFs are critical for improving hu-
man nutrition, there are significant obstacles
to overcome. First, scaling up ASF produc-
tion comes at a potential environmental cost
since livestock and fish production releases
methane (CH_4) and nitrous oxide (N_2O) to
the atmosphere, thus contributing to global
warming. Depending on the methodology, it
is estimated that the livestock sector contrib-
utes between 8% and 18% of the total global
greenhouse gas (GHG) emissions (IPCC

2006; Steinfeld et al. 2006). The amount of
GHG emissions are closely linked to size of
the livestock population as well as to the size
of the animal, with non-dairy cattle being a
major source of methane emissions (O'Mara
2011). Therefore, optimizing the size, produc-
tivity and composition of the national live-
stock and fisheries sectors to maximize the
nutritional benefits whilst minimizing GHG
emissions is an important area of future
research.

Additionally, a substantial proportion of
the world's undernourished population is
vegetarian for cultural reasons. The DHS for
India—which accounts for around one-third
of the world's population of stunted chil-
dren—suggests that around one-third of
Indian adults are vegetarian or lacto-
vegetarian. Short of radical cultural shifts,
these populations will likely continue to rely
on legumes as their key source of protein.
While legumes were not associated with
stunting in our full sample results, we did ob-
serve a significant association between le-
gume consumption and child growth in the
South Asian sample (table 6), suggesting that
legumes play a special role in this region that
they do not in other populations. Clearly, in-
creasing consumption of ASFs in India and
Nepal is challenging, and may require a mix
of agricultural policies and tailored behav-
ioral change designed to either increase ASF
consumption (dairy particularly among lacto-
vegetarians) or appropriately supplement
diets with legumes or fortified infant cereals.

The importance of ASFs for child nutrition
therefore has important ramifications for fu-
ture research and for international and na-
tional investments in agriculture. We see
three lines of attack: (a) as economists, we
are used to thinking that large price differen-
tials present opportunities for arbitrage. In
the case of ASFs, this is clearly not occurring,
suggesting significant barriers to trade. An
understanding of the relative roles played by
policy decisions (such as tariff levels), tech-
nology (addressing perishability issues), or a
combination of the two (e.g., phytosanitary
regulations) will help inform appropriate pol-
icy changes and interventions that should
lower these barriers and in turn reduce these
price differentials. (b) Understanding
whether improvements in ASF value chains
can improve diets of pre-school children.
Randomized control trials may be difficult to
implement but it might be possible to exploit
natural experiments such as improved access

to these value chains following infrastructure improvements, such as roads. (*c*) Increased investments in research that will lead to increased productivity in ASF sectors and, relatedly, assessing whether such improvements, possibly twinned with demand-side interventions such as nutrition behavior change communication, can increase pre-school child ASF consumption and in turn reduce stunting.[10] More generally, we see such a research portfolio as part of efforts to shift the international and national agricultural research and policy agendas away from their dominant focus on food quantity towards a more balanced portfolio that pays increased attention to diet quality.

Supplementary Material

Supplementary material are available at *American Journal of Agricultural Economics* online.

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[10] Currently, the vast proportion of agricultural research and development expenditures for lower-income countries has been directed towards staple crops, with livestock and fisheries accounting for approximately 12% of CGIAR (Consultative Group for International Agricultural Research spending), according to David Laborde (personal communication). This does not include national agricultural expenditures; we suspect that the share of the total agricultural budget devoted to livestock is unlikely to be higher than this.

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