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PRO-POOR HPAI RISK REDUCTION

Animal Source Food Consumption and Nutrition among Young Children in Indonesia: Preliminary Analysis for Assessing the Impact of HPAI on Nutrition

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Preface

Since its re-emergence, HPAI H5N1 has attracted considerable public and media attention because the viruses involved have been shown to be capable of producing fatal disease in humans. While there is fear that the virus may mutate into a strain capable of sustained human-to-human transmission, the greatest impact to date has been on the highly diverse poultry industries in affected countries. In response to this, HPAI control measures have so far focused on implementing prevention and eradication measures in poultry populations, with more than 175 million birds culled in Southeast Asia alone.

Until now, significantly less emphasis has been placed on assessing the efficacy of risk reduction measures, including their effects on the livelihoods of smallholder farmers and their families. In order to improve local and global capacity for evidence-based decision making on the control of HPAI (and other diseases with epidemic potential), which inevitably has major social and economic impacts, the UK Department for International Development (DFID) has agreed to fund a collaborative, multidisciplinary HPAI research project for Southeast Asia and Africa.

The specific purpose of the project is to aid decision makers in developing evidence-based, pro-poor HPAI control measures at national and international levels. These control measures should not only be cost-effective and efficient in reducing disease risk, but also protect and enhance livelihoods, particularly those of smallholder producers in developing countries, who are and will remain the majority of livestock producers in these countries for some time to come.

This report looks at the nutritional impact of HPAI in Indonesia.

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More information

For more information about the project please refer to www.hpai-research.net.

1. Introduction

Globally, highly pathogenic avian influenza (HPAI) has now been reported in more than 40 countries, with 385 human cases in 15 countries resulting in 243 deaths (World Health Organization (WHO) 2008) (FAO-EMPRES. 2007). The world has focused primarily on containing the disease and preventing a global influenza pandemic - concentrating resources into bio-security and vaccine development. However, the livelihood and indirect health consequences of HPAI have yet to be fully quantified nor strategies for mitigation of these kinds of effects promulgated. Macro-level estimates showing losses in the order of 140 million birds and $10 billion in the poultry industry call for a better understanding of livelihood impact at the household and individual levels (The World Bank 2008).

One aspect of livelihood in developing countries that has been largely neglected is the effect of HPAI disease, prevention and control strategies on nutrition. The degree and magnitude of such a nutrition impact may be a function of several factors, beginning with changes in poultry product consumption by household members. An HPAI outbreak may have income and price effects that could influence the consumption of all food commodities and hence, the nutrition of household members. Perhaps more importantly, HPAI outbreak leads to a discrete change in preferences away from poultry implying a consumption shock to poultry products.

Infants and young children are likely the most vulnerable population group to the nutritional consequences of an HPAI shock. The recent landmark Lancet series on Maternal and Child Nutrition reported that 32% of all children living in developing countries who are less than five years of age are stunted [height-for-age (HAZ)< -2 SD], 19.3 % are underweight [weight-for-age (WAZ)<-2 SD], and 3.5% are wasted [weight-for-height (WHZ)<-2 SD] (Black et al. 2008). It is usually in the early stages of the complementary feeding period between 6-12 months of age when infants from resource-poor settings experience marked growth faltering - as solid foods are introduced into the diet and infectious disease exposures increase (Shrimpton et al. 2001). This is also the period when micronutrient deficiencies may arise, in particular for those micronutrients that are inadequately provided by breastmilk.

Many studies have shown increased vulnerabilities and highly prevalent deficiencies among young children for the following micronutrients: iron; zinc; vitamin A; iodine; vitamins B6 and B12 (Dewey and Brown 2003). Deficiencies in these vitamins lead to impaired growth and cognitive development and higher rates of morbidity and mortality in children. Indeed, there are serious, irreversible consequences of micronutrient deficiencies and childhood undernutrition more generally, that will manifest in adulthood and even into the next generation (Victora et al. 2008). The plant-based diets lacking in ASF for many living in developing countries is often cited as an important cause of micronutrient deficiencies.

Animal source foods (ASFs) offer both higher concentrations and more bio-available matrices for critical micronutrients when compared to plant-derived foods. Thus, the presence of ASF in the diet can be an efficient delivery mechanism during periods when requirements are high (pregnancy, lactation, early infancy and childhood, and adolescence). Poultry meat, for example, is a good source of iron and zinc, while eggs provide vitamin A, vitamin B12 and riboflavin in forms available for absorption. Micronutrient supplementation and fortification are two strategies that have been extensively applied in global efforts to reduce micronutrient deficiencies, however, problems of sustainability and cultural acceptability are often present (Leroy and Frongillo 2007). Food-based strategies are preferable from the perspective of multiple micronutrients and acceptability, though there can be issues of affordability and access especially in vulnerable populations (Pachon et al. 2007;Ruel 2001). ASFs may be "luxury goods" for households, beyond the reach of poor households, or compromised during periods of economic difficulties such as a HPAI outbreak.

In considering the possible impact of HPAI on child nutrition in Indonesia, it is thus imperative to understand the role played by poultry (meat and eggs) in conjunction with other ASFs in child nutrition. Hence, in this paper we first analyze in detail the role played by poultry and other ASFs in determination of nutritional outcomes such as wasting, stunting, being underweight or being anemic in the children in the age group 1-3 years. We also assess the impact on more continuous markers such as Z scores.

Animal source foods (ASF), which include poultry meat and eggs, are critical for micronutrient nutrition and known to be both income and price elastic. We assess the potential impact of a HPAI outbreak by treating the event as an income and consumption shock. As observed in most countries that have experienced an outbreak (or had a HPAI scare), there had been a drastic change in preferences away from poultry.[1] Unlike the change in incomes that would apply to participants in the poultry value chain and related sectors, this demand shock emanating from changes in preferences for poultry products would apply to children in all households. Based on our data we conjecture the income shocks to be small in general as income sources for most households in our sample are substantially diversified with poultry being only one among several other activities even in agricultural households.

With changes in income the consumption of all food items is likely to change. Moreover, income may have effects on nutrition that are independent from consumption. For example, reduced income may decrease access to health care or worsen hygiene and sanitation conditions in the household with implications on child nutrition in particular. Though the sample is characterized with small share of poultry in household's income implying a negligible income shock but it remains a possibility for some households who have a big share of their income coming in from poultry, a phenomenon that the dataset does not allow us to capture. Moreover, we have no information on participants in the poultry value chain except farmers who will experience a fall in their incomes. In reality, other related sectors will also experience a fall in returns (such as in tourism) known in literature as knock on effect.

Figure 1 illustrates the hypothesized pathways for the determining factors at individual, household, and community levels on the two outcomes explored by this study (shaded purple boxes), child consumption of ASF and the nutrition outcomes of growth and anemia.

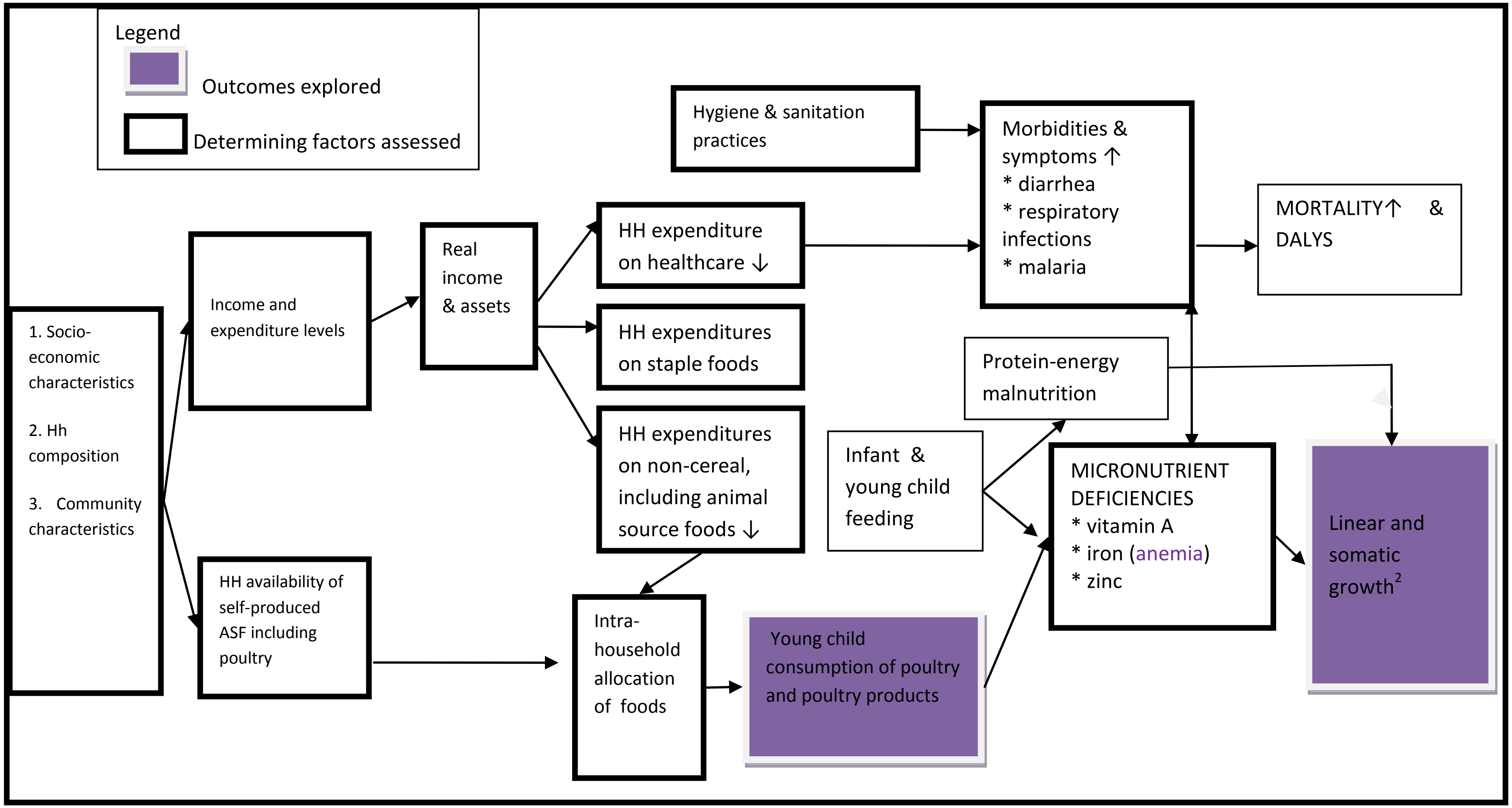
Indonesia, where HPAI subtype H5N1 was first found in 2003, was selected for this analysis for several reasons. First, HPAI has spread throughout the country and since 2006 is considered endemic in several of these regions; more cases and deaths have been reported here than in any

[1] Admittedly, the response of households as consumers is different in epidemic as opposed to an endemic state which is now the case in Indonesia.

other country. From August 2003 to February 2007, there have been 11.3 million chicken deaths (Sumiarto and Arifin 2008). Second, the Indonesian Family Life Surveys (IFLS) provide data on nutrition in the Indonesian population and the factors that may be affecting poultry and poultry product consumption. IFLS-4 data will be released in 2009 that directly examines the HPAI effects on livelihood. The objectives of this analysis were therefore to: 1) characterize the importance of animal source foods (ASF), and more specifically poultry and poultry products, in the Indonesian infant and young child diet and nutrition; 2) to identify the factors associated with ASF and poultry and poultry product consumption and (3) obtain impacts on nutrition outcomes of HPAI shock (taken as conservative) in Indonesia through supply/income and demand shocks. HPAI outbreak would likely bring in a discrete reduction in poultry consumption among children.

We have thus hypothesized that HPAI has had or could lead to detrimental effects on micronutrient nutrition among susceptible populations, infant and young children living in poor households. This study, intended as an initial phase for understanding HPAI effects on livelihood, health, and nutrition, will use the Indonesian Family Life Survey -3 conducted in 2000 to examine the factors associated with ASF consumption, and subsequently, explore the hypothesis that ASF consumption is associated with better nutrition outcomes contingent on varying levels of other conditions.

Figure 1. Impact pathways for HPAI shock on nutrition[1]



1 Black-outline indicates part of pathway included in this analysis.
2 Linear growth is measured by height-for-age Z scores, while somatic or body growth is measured by weight-for-age and weight-for-height Z score outcomes.

2. Data and Methods

Sample and survey methods

The Indonesian Family Life Survey (IFLS) collects information on individuals, households and communities throughout the country at different points in time. The first wave (IFLS-1) was fielded in 1993-94, representing about 83% of the Indonesian population living in the 13 of the 26 Indonesian provinces in 1993 (Strauss et al. 2004a). The second wave (IFLS-2) took place in 1997-98, and the third wave (IFLS-3) took place in 2000. Due to effective re-contact protocols, the attrition rates are particularly low, even when compared to similar surveys in developed countries. In 2000, 91.3% of the targeted IFLS-1 household members where re-contacted in 2000 (they were either interviewed or had died). A fourth wave was fielded in 2007, but at the time of writing it was not publicly available.

The IFLS-3 household questionnaires included information on education, health, employment, household expenditure consumption, and socio-economic and demographic characteristics. There was also a special module for ever-married women between 14 and 49 years and a module with health measurements. The IFLS-3 community-level survey includes information on health and education centers, prices, environmental conditions, etc. Strauss et al. (2004) describes in detail the re-contact protocols and the proper ways to link the information across books and across waves of the survey.

At the household level, respondents were asked the value of total expenditures in the last week on the various food categories. They were subsequently asked the value of foods either self-produced or received from another source in the same food categories. The animal source food groups included the following: 1) beef, mutton, water buffalo, and the like; 2) chicken, duck, and the like; 3) fresh fish, oysters, shrimp, squid, and the like; 4) salted fish, smoked fish; 5) jerky, shredded beef, canned meat, sardine and the like; 6) eggs; 7) fresh milk, canned milk, powdered milk and the like.

For the child-level data, household members including the children themselves when they were old enough were asked questions about child education, morbidity, health care treatments and services, and diet. For diet measures, the respondent was asked how many times in the last week did the child consume a specified food group which included: tubee; eggs; fish; meat/poultry; milk; vegetables; banana; papaya; carrot; and mango. Responses were grouped into no consumption, one time, 2-3 times, 4-6 times, or greater than 6 times. Child morbidity was obtained by inquiring how many times in the last 4 weeks did the child experience the morbidity.

Nurses were trained to take the physical measurements of health for household members, with additional training provided for taking anthropometric measures and hemoglobin concentrations. These nurse health workers took blood spots from household members older than one year for use in the Hemocue system, which was calibrated daily. Digital SECA scales, calibrated weekly, were used for weight measures, and --- for recumbent length, and --- for height. Repeat visits to households were made in the case of broken scales or Hemocue machines (Strauss et al. 2004b; Strauss et al. 2004a).

Variable definitions

Dichotomous food group variables were created for the ASF food groups - meat or poultry, eggs, milk, and fish – to investigate the presence or absence of the food in the child diet. As well, two kinds of frequency variables were created for the consumption variables. The first was again a series of 4 dichotomous variables containing varying cut-off levels for frequency of consumption by the child. These were based on the lower value for reported consumption categories: at least 1 time consuming food; at least 2 times; at least 4 times; and at least 7 times. The second kind was one variable assigning a level of frequency to the child based again on the lower value for reported consumption. If a mother reported the child had consumed a food 2-3 times, the child was assigned 2. A composite variable for any ASF food consumed in the last week was also created that incorporated all of the ASF groups.

Per capita income quartiles were created using the full IFLS-3 sample and applied to this sub-analysis of households with children 6-36 months of age. Per capita expenditures were calculated by summing all food and non-food current expenditures. Given the potentially smaller measurement error in expenditure per capita data, expenditures have been taken as an indicator of economic status. Toilet type as a matter of household hygiene was analyzed in two variables. The first stratified outside into private, shared or public, and no toilet on the premise that there may be some health effect related to a toilet used by several individuals. The second variable was dichotomous collapsing use of any toilet – private or public – compared with no toilet. Similarly, household source of drinking water was collapsed into two categories of water source in the home and outside.

Nutrition markers were the primary outcomes of interest in this paper. Parameters were identified from the IFLS data that best represented our hypothesized HPAI effect on micronutrient nutrition: anthropometry; hemoglobin concentration; and morbidities. Using these parameters, additional variables were created to better measure this effect. Z scores were generated weight-for-age (WAZ), height or length for age (HAZ), and weight-for length (WHZ) using the WHO Growth Standards (World Health Organization (WHO) 2006). A child was classified as *stunted* when HAZ < -2 SD; as *underweigh*t when WAZ < -2SD, and as *wasted* when WHZ < -2 SD. Mother's body mass index (BMI) was created using: weight (kg)/height (m)^2. Children ages 6 to 36 months were classified as *anemic* if hemoglobin concentration was reported to be less than 11.0 g/dl. Mothers were considered *anemic* if they were non-pregnant (≥15 yr) and hemoglobin was less than 12.0 g/dl, or they were pregnant and hemoglobin was less than 11.0 g/dl (Stoltzfus and Dreyfuss 2008). In addition to the reported morbidities assessed – eye infection, fever, diarrhea – an additional variables for acute respiratory infection was created and defined as cough plus short, rapid breathing.

Data Analysis

Bivariate analyses were run using *t* tests and Pearson's chi-squared test of independence. On the premise that wealth plays an important role in determining ASF consumption, socio-economic characteristics were stratified by per capita expenditure quartiles, and reported for quartile 1 (poorest) and quartile 4 (richest).

To assess the determinants of the children's consumption patterns, we use a system of four equations to estimate the probability of a child consuming meat/poultry, eggs and milk at least once a week.[2] The binary variable, whether the child does or does not consume these animal source foods at least once a week is specified as a function of different household, mother, and child characteristics. We estimate the equations as a multivariate probit. When specified as independent probit equations, the underlying assumption is that across equations there is a zero correlation between their disturbance terms that subsumes the unobserved variables (such as people's personal beliefs and perceptions). It is reasonable to expect that unobserved variables affecting the probability of consumption of any one of these ASFs would be correlated with the unobserved variables affecting the consumption of others. The multivariate probit specification that we employ allows for non-zero correlation between the error terms across equations.

Following this, we assess the linkage between the different children nutrition measures and their consumption of animal source foods with a focus on poultry products. Our hypothesis is that ASF consumption will be positively correlated with anthropometric outcomes (HAZ, WHZ) and hemoglobin concentrations, and negatively correlated with stunting, wasting, and anemia.

We employ the multivariate probit specification for wasting, stunting, underweight and anemia and seemingly unrelated regressions (SUR) for modeling WAZ, WHZ, HAZ, and hemoglobin concentrations for children ages 12-36 mo for reasons identical to ones discussed above.[3] The unobserved variables that affect one anthropometric or nutrition measure are likely to be correlated with other nutrition measures.

The Multivariate Normal Density Function[4]

The multivariate probit model can be presented as an n-dimensional system of equations as given below. The unobserved latent variable y_i^* for the i^{th} household in each equation is defined as:

$$y_i^* = x_i'\beta_i + \varepsilon_i \quad i = 1, 2, \ldots, n \tag{1}$$

What is observed is the binary variable whether or not child in the household had a consumption of the relevant ASF with a frequency of at least once a week. The observed variable takes the value

$$\begin{aligned} y_i &= 1 \quad if \ y_i^* > 0 \\ y_i &= 0 \quad if \ y_i^* \leq 0 \quad i = 1, 2, \ldots, n \end{aligned} \tag{2}$$

As in the uni-variate probit model, we assume that the expected value of the disturbances is zero, and we normalize their variance to 1. There are however two structural differences with respect to univariate probit models. First, both the expected value and the variance are conditional on both sets of explanatory variables. Secondly, as discussed above the model allows for a non-zero correlation between the disturbance terms across equations. The model is then estimated via Maximum Likelihood.

[2] In case of consumption frequencies the equation estimated is a multinomial probit.
[3] The variables WAZ, WHZ, HAZ, and hemoglobin are continuous.
[4] Greene(2003)

The SUR model

The Seemingly Unrelated Regression model is specified as a system of four equations with dependent variables WAZ, WHZ, HAZ and hemoglobin concentrations for children.

$$y_i = \alpha + x_i^{'}\beta_i + \varepsilon_i \quad i = 1, 2, 3, 4 \qquad (3)$$

Where y_1 is WAZ, y_2 is WHZ, y_3 is HAZ and y_4 is hemoglobin concentration. The main model assumption distinct from Ordinary Least Squares is that the error terms are correlated across equations. In the first three equations the explanatory variables are identical while the fourth one includes mother's hemoglobin concentration also as an explanatory variable. Given that all explanatory variables are not identical in all equations the Generalized Least Squares (GLS) estimate are likely to be different from OLS estimate.

Assessment of the potential impact of HPAI on child nutrition

In order to derive the counterfactual scenario of effect of changes in income of households brought about by HPAI, we obtained the simulated impact on Z scores of children in households that engage in poultry production and depend on it as their source of livelihood. Restricting the sample to households that engage in poultry production, a conservative range of income shock between 10-30% following an HPAI outbreak is performed on these households. IFLS data presents livestock and poultry as an aggregate category. As the data is not disaggregated to have poultry as a separate activity, distribution of income sources between livestock, poultry and fishpond had to be assumed. Following summary evidence from World Bank Survey in central Java where higher income household's livestock portfolio is biased in favor of non-poultry livestock, we assigned the highest share of income from poultry in aggregate livestock income to lowest income quartile households (at 75%). The lowest share was for highest income quartile at 25% with the middle income category set at 50%.

As discussed above HPAI outbreak also applies a shift in preferences away from poultry. With changes in poultry and egg consumption by the children, consumption of other food items should also adjust. Since we do not have data for pre- and post- HPAI outbreak in Indonesia, we compare the households with zero poultry consumption by children similar in other respects but differing only in poultry consumption to assess the potential impact on nutrition through the consumption channel.

In order to capture the effect of a consumption shock we thus apply the idea of propensity score matching (PSM). PSM constructs a statistical comparison group based on a model of the probability of participating in the treatment: *P(X)*=Pr(*d=1|X*) where X is a set of observables likely to be correlated with participation in treatment (i.e. maintain positive poultry consumption) as well as with outcomes (nutrition markers). D=1 denotes treatment. Propensity score, P(X), is constructed from probit model of program participation controlling for all X variables that jointly affect the probability of participation in the treatment group and the outcome of interest, the nutrition outcomes.

Implementation of PSM requires a region of common support (where distributions of propensity scores for treatment and comparison group are overlapping) and that balancing property be satisfied. For balancing property to be satisfied, average propensity score and mean of X variables are the same within blocks (usually quantiles) of the propensity score distribution. With these conditions satisfied an estimator for matching needs to be chosen. We have opted for the kernel matching method here. All methods involve some trade offs. Hence we implement different matching estimators but report only the Kernel based matching.

The difference in outcomes between the children in the treatment and control groups that have similar propensity scores (conditional (on a set of observables probability of being selected into treatment) helps identify the average effect of the treatment on the treated (ATT). We estimate the ATT in regions of common support.

In the sample there are two types of households those who have non-zero consumption of poultry products (meat and eggs) and those that have zero consumption. The children who have zero consumption already cannot have their consumption of poultry products affected because of a HPAI outbreak. The children in this group comprise the control group. The children who have non-zero consumption comprise the treatment group where the treatment is “having/maintaining positive consumption of poultry products.” Identification of treatment effects on nutrition will capture the effect on child nutrition of poultry products’ consumption in households that are similar to children that have zero consumption of poultry products. In these households HPAI can bring in nutrition loss on an average by the amount that is negative of the gain by maintaining positive consumption. The ATT measures the effect on children in households that are most likely to reduce their consumption of poultry products to zero for any reason of which HPAI is one highly plausible one.

3. Results

Characteristics

There were a total of 1,931 households with 2019 children ages 6-36 months (**Table 1**). Fewer children were included in this sub-sample from IFLS-3 from the highest quartile compared to the lowest; in addition, this group was slightly younger and had a lower birth order. At the time of the survey, 70% of mothers of infants ages 6 to 11.9 mo reported to be breastfeeding, 55% of mothers of children between 12 and 23.9 m, and 24.3% of mothers between 24 and 35.9 mo were breastfeeding. Age when water and solid foods were introduced and age of weaning showed great variability in the small number of mothers reporting.

Table 1. Child and household characteristics

	All	Lowest quartile of PCE	Highest quartile of PCE
	Children n=2020 Households n=1,931	Children n=614 Households n=582	Children n=337 Households n=326
Child age (mo)	20.2 (±8.9)	20.5 (±9.1)	19.7 (±8.7)
Child birth order	2.2 (±1.3)	2.6 (±1.4)	1.8 (±1.0)
Breastfeeding (n=388)[1]			
Age water introduced	1 mo	2 mo	1 mo
Age food introduced	4 mo	4 mo	3.75 mo
Age weaned	24 mo	24 mo	24 mo
Body mass index of non-pregnant mother	21.9 (±3.7)	21.1 (±3.2)	22.9 (±3.6)*
Hemoglobin concentration of non-pregnant mother	12.2 (±1.5)	12.2 (±1.5)	12.3 (±1.6)
Maternal education			
No education	6.7	11.6	2.1*
Primary school	44.7	61.9	16.7
Junior high	18.5	14.2	16.2
Senior high	24.0	12.0	42.2
Post-secondary	6.0	0.4	22.9
Region of residence			
Urban	42.8	30.2	65.9*
Rural	55.2	69.8	34.1
Religion (n=1,932)			
Islam	90.0	93.3	88.7*
Protestant	3.6	2.8	3.4
Hindu	4.6	3.1	4.6*
Other	1.8	0.8	3.3
Agriculture employment			
Head of household	26.9	34.3	14.2*
Any member of household	40.6	57.1	19.2*
Household per capita expenditure (rupiah)[1]	118,683	56,893	328,389*
Total household assets (rupiah)[1]	1.47e+07	9,560,000	398e+07*
Household budget allocations (%)			
Food	66.1 (±16.1)	70.9 (±13.1)	54.8 (±19.2)*
Education	3.8 (±5.7)	4. 3 (±5.7)	3.0 (±5.7)*

	All	Lowest quartile of PCE	Highest quartile of PCE
	Children n=2020 Households n=1,931	**Children n=614 Households n=582**	**Children n=337 Households n=326**
Health care	2.1 (±4.6)	1.7 (±4.2)	3.0 (±5.4)*
Clothing, furniture, etc.	28.0 (±14.8)	23.1 (±11.3)	39.1 (±18.7)*
Electricity in the home	89.1	82.5	96.0*
Hygiene – toilet type (n=1,932)			
Private toilet	61.4	48.8	83.7*
Shared or public toilet	10.2	8.4	7.4*
No toilet	28.4	42.8	8.9*
Water source in the home	42.8	30.0	69.8*

[1] Median reported.

*Significantly different than lowest quartile by chi squared or t test.

Excluding the 11% of mothers who were pregnant at the time of the survey, BMI and hemoglobin concentrations are presented here and show differences by PCE quartile for the former only. Mean number of years of education was 5.7 (±3.5) for PCE quartile 1, 7.4 (± 3.8) for quartile 2, 8.7 (±3.9) for quartile 3, and 10.9 (±3.9) for quartile 4. A total of 47% of mothers reported having no formal education, with significant differences apparent between quartile 1 (69%) vs. quartile 4 (17%) ($P<0.001$).

Nearly all households reported being of Muslim faith, with a small drop in this percentage for the highest quartile and the remaining seeming evenly distributed to other faiths. Households in the lowest PCE quartile were predominantly located in rural areas. Agricultural employment tended to be clustered in the lowest PCE quartile; over one-half of reporting households from PCE quartile 1 were employed through this sector. Large disparities between quartile groups in median PCE and total value of assets were observed in this population. Over one-half of the sample reported owning no livestock assets. Allocations for household expenditures were higher for food and education in the poorest quartile and higher for medical expenses and clothing/furniture, etc. categories in the richest quartile. Nearly all households reported having an electricity connection, though 18% in the lowest PCE quartile reported no electricity connection.

There were large differences in both toilet type and source of drinking water by PCE quartile. Most families reported taking drinking water from either piped water (25.5%), a pump (28.3%) or a well (32.4%). 93% of households reported boiling their water before drinking, regardless of source. Prevalence of morbidities did not vary by quartile of PCE, with the exception of fever among children 6-11.5 mos (Table 2).

Table 2: Prevalence of morbidity in previous month, by age of child and extreme PCE quartile (%)

	All	Lowest quartile of PCE	Highest quartile of PCE
Diarrhea			
6-11.5 mo	21.8	14.9	19.3
12-23.9 mo	21.6	19.6	22.1
24-35.9 mo	18.0	17.3	15.8
Acute respiratory illness			
6-11.5 mo	3.1	5.4	5.1
12-23.9 mo	3.5	1.6	3.8
24-35.9 mo	5.5	5.6	5.0
Fever			
6-11.5 mo	56.5	58.2	43.4*
12-23.9 mo	53.8	52.0	50.7
24-35.9 mo	49.2	42.3	51.8
Eye infection			
6-11.5 mo	5.8	5.7	7.2
12-23.9 mo	4.2	4.0	2.1
24-35.9 mo	4.8	2.8	4.4

*Significantly different than other PCE quartile, by chi squared.

Infant and young child consumption

High proportions of children ages 6 to 36 mo from this sample were reported to have consumed some form of ASF in the previous seven days of the survey (Table 3). There were large increases in the proportion of children consuming ASFs after one year, with the exception of milk. Eggs are the most widely consumed ASF after one year, while milk consumption is more highly prevalent from 6 to 11.9 mos (Figure 2). Meat and poultry consumption remained low for all age categories, especially for children from the poorest households. Differences in meat/poultry frequencies by PCE quartile are more marked than the other food groups. In children over one year, eggs and fish are more evenly spread than the other food groups, and consequently demonstrate more variability across frequencies; the PCE quartile differences are also attenuated. Milk consumption demonstrates a U-shaped distribution, with higher proportions reported in the upper and lower frequency categories in all three age categories. By the second year of life, the largest disparities in consumption between the poorest and richest households are in milk.

Other food group categories were assessed, including fruits and vegetables that might supplement quantity or enhance absorption of particular micronutrients. While one-half of the children had received vegetables 7 or more times in the previous week, 20% had none. 46.5% of the children had taken carrots, 16.9% had mangos, and 43.7% had papayas one or more times in the previous week.

Nutritional Outcomes

Mean HAZ in this population was -1.14 (±1.81), mean WAZ was -0.86 (±1.33), and mean WHZ was -0.29 (±1.61). The mean hemoglobin concentration was 10.2 (±1.47). Among all children, 30% were classified as stunted, 17% underweight, 11% wasted, and 65% anemic. Hence, anemia is most prevalent problem in the sample of children. Prevalence of undernutrition varied by age, with the exception of wasting (Table 4). For children ages between 12 and 36 months, being in the upper PCE quartile reduced the odds of stunting, underweight, and anemia

Figure 2. Frequency of ASF consumption among infants 6-36 mo, by PCE quartile

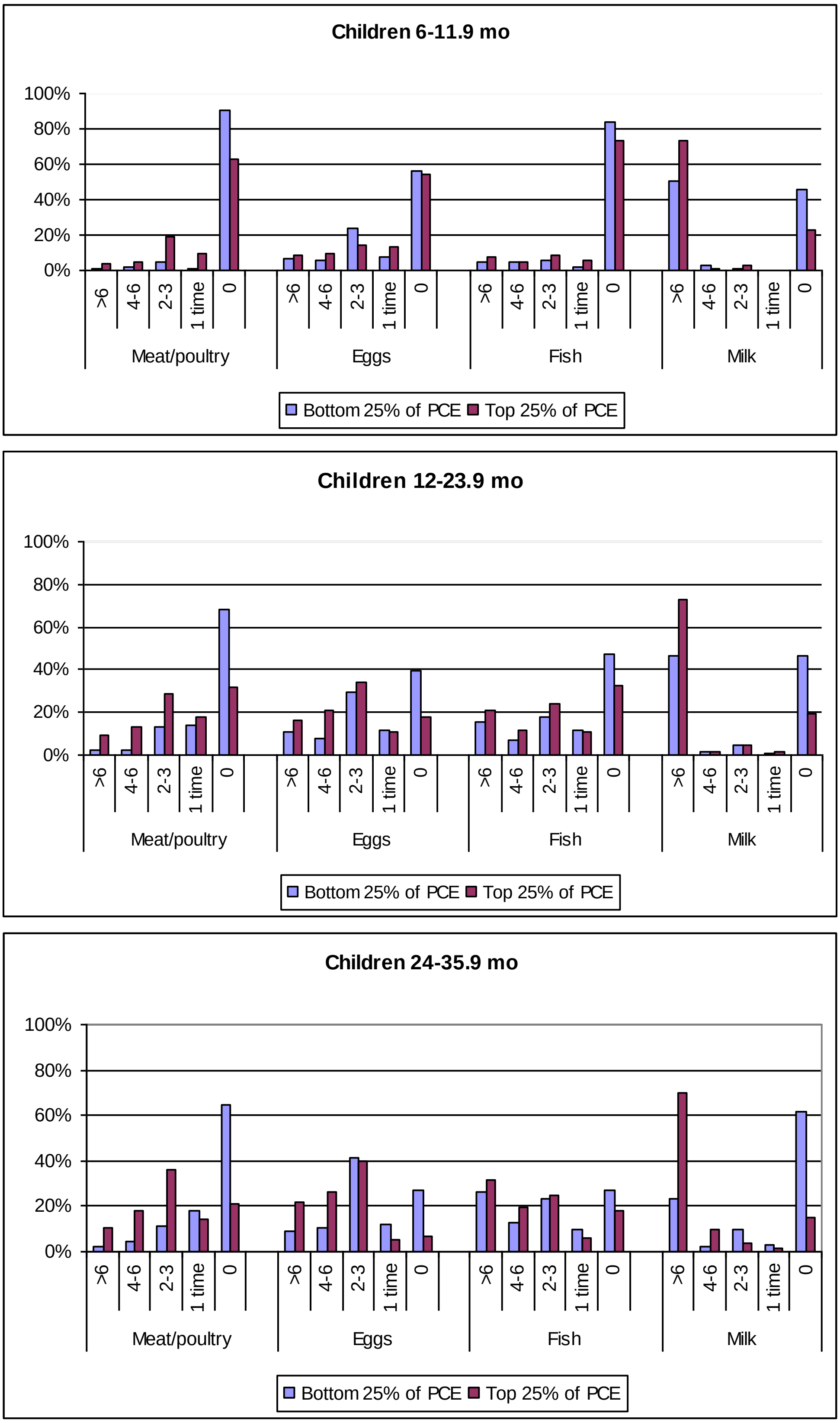


Table 3: Proportion of young children receiving food in last 7 days, by age and extreme quartiles (%)

	All	Lowest quartile of PCE	Highest quartile of PCE
Meat or poultry			
6-11.5 mo	19.5	9.2	37.4*
12-23.9 mo	48.1	32.0	68.6*
24-35.9 mo	56.0	35.5	79.0*
Eggs			
6-11.5 mo	44.5	44.0	45.8
12-23.9 mo	74.5	60.4	82.1*
24-35.9 mo	83.6	73.0	93.0*
Milk			
6-11.5 mo	59.5	53.9	77.1*
12-23.9 mo	65.0	53.3	80.7*
24-35.9 mo	59.7	38.7	85.1*
Fish			
6-11.5 mo	22.9	16.3	26.5
12-23.9 mo	61.7	52.4	67.1*
24-35.9 mo	81.7	72.6	81.6*
Animal source food			
6-11.5 mo	79.4	76.6	91.6*
12-23.9 mo	95.2	90.7	98.6*
24-35.9 mo	97.9	94.0	100*

Table 4: Prevalence of undernutrition, by age and extreme PCE quartile (%)

	All	Lowest quartile of PCE	Highest quartile of PCE
Stunted			
6-11.5 mo	22.9	26.9	20.5
12-23.9 mo	41.4	43.6	29.3*
24-35.9 mo	46.1	59.7	18.4*
Underweight			
6-11.5 mo	15.4	19.2	9.6
12-23.9 mo	22.8	26.2	16.4*
24-35.9 mo	30.6	39.9	19.3*
Wasted			
6-11.5 mo	11.6	11.4	12.1
12-23.9 mo	11.0	12.0	9.3
24-35.9 mo	10.9	12.1	7.9
Anemic			
6-11.5 mo	na	na	na
12-23.9 mo	71.8	76.5	65.2*
24-35.9 mo	57.4	63.6	46.2*

Regression Modeling

Socio-demographic, economic, hygiene and sanitation, and morbidity covariates were tested in modeling ASF consumption and nutrition outcomes. Per capita expenditure was a strong predictor of consumption of all ASFs including for meat and poultry and eggs (Table 5). Mother's education level was also an important determinant for all ASF foods. Increasing child age was associated with *meat or poultry*, *eggs,* or *fish* consumption. Having a household member employed in agriculture was negatively correlated to *meat or poultry*, and positively related to *fish* consumption. Children living in households producing their own eggs were more likely to consume eggs.

Consumption of meat or poultry showed a significant protective effect on childhood anemia, that is most prevalent among children (Table 6). Milk consumption showed a significant negative association with a child being classified as *underweight* or *stunted*. In case of Z scores and hemoglobin concentration no significant impact of meat/poultry or egg consumption was obtained (**Table 7).** Milk consumption did have an impact on weight for age z scores and z scores for length. Qualitatively identical results are obtained in regressions with frequencies (results have not been reported).

Child age was positively correlated with both anthropometric outcomes at a declining rate. This relationship was reversed for anemia, showing a protective effect with increases in age. Per capita expenditure was a significant determinant of improved nutrition outcomes of weight-for-age and height-for-age, as were other economic indicators such as age of household head and value of assets. Male children were at higher risk for all undernutrition outcomes. Mother's education protected against the child being underweight and anemic. Access to health care as measured by number of health posts showed a protective effect against being underweight and wasted. Mother's hemoglobin concentration was a strong predictor of anemia in children. Results are qualitatively similar with frequencies of consumption as explanatory variables with an important difference. Working with frequencies meat and poultry consumption has a strong effect on stunting that is not obtained in case of dichotomous ASF consumption variables. The effect on anemia is significant in a model with frequencies as well.

Significant correlations for disturbance terms were shown for the equations of: stunting and underweight; the stunting and anemia; meat/poultry and egg consumption; and meat/poultry and milk consumption. The joint hypotheses of zero correlation between the disturbance terms in the system was rejected at conventional levels of confidence. This implies a preference for multivariate probit over probit models. Additional results related to frequency of ASF consumption and nutrition outcomes are found in the Appendix 1 (Table A1). Determinants of frequencies of consumption are assessed using multinomial probit. The results have not been presented. There is nearly one to one correspondence between the predictors of dichotomous consumption variables and consumption frequency.

Table 5: Determinants of ASF consumption (results from multivariate probit regressions)

	Meat / Poultry	Eggs	Milk	Fish
Child age (yr)	0.335***(0.057)	0.417***(0.063)	-0.0356 (0.058)	0.541***(0.059)
Child sex	0.0116 (0.067)	-0.0694 (0.075)	0.0673 (0.069)	-0.170**(0.070)
Per capita expenditure (Rp)	0.331***(0.061)	0.167**(0.067)	0.194*** (0.065)	0.169***(0.057)
Agriculture employed household	-0.283***(0.082)	-0.0683(0.092)	-0.0882 (0.084)	0.158* (0.086)
Years of education of the mother	0.0546*** (0.0099)	0.0568*** (0.011)	0.0586*** (0.010)	0.0265** (0.010)
Rural residency (1=rural)	-0.0651 (0.081)	-0.0833 (0.092)	-0.313*** (0.083)	0.0590 (0.085)
Electricity (1=yes)	0.434***(0.13)	0.410***(0.13)	0.321**(0.13)	0.0281(0.13)
Islam religion (1=yes)	-0.386***(0.11)	0.203* (0.12)	0.0329 (0.11)	-0.365*** (0.12)
Value of household assets	-9.12e-10* (4.73e-10)	-4.78e-10 (5.02e-10)	1.35e-09** (6.22e-10)	-7.04e-10 (4.83e-10)
Size of household	0.0190* (0.011)	0.0134 (0.013)	-0.00540 (0.011)	0.0256** (0.012)
Food share in total budget	0.320 (0.25)	0.265 (0.28)	-0.393 (0.26)	0.843*** (0.26)
HHautochicken	0.0000161 (0.000010)	0.0000144 (0.000013)	-0.00000158 (0.0000093)	0.00000436 (0.000011)
Hhautoeggs	0.0000158 (0.000029)	0.0000860** (0.000041)	-0.0000259(0.000028)	0.0000172(0.000034)
HHautomilk	0.0000914** (0.000044)	0.0000165 (0.000040)	0.0000323 (0.000031)	-0.0000210 (0.000031)
Constant	-1.557***(0.37)	-1.157***(0.41)	0.154(0.38)	-1.173***(0.38)
Observations	1539	1539	1539	1539

*P<0.1 **P<0.05 *** P<0.001, (Terms in parentheses represent standard errors).

Table 6: Determinants of nutrition outcomes

	Underweight		**Stunted**		**Wasted**		**Anemic**	
	Coef.	**P>|z|**	**Coef.**	**P>|z|**	**Coef.**	**P>|z|**	**Coef.**	**P>|z|**
Meat/poultry	-0.062	0.46	-0.094	0.23	-0.003	0.98	-0.143	0.07
Eggs	0.028	0.78	-0.064	0.50	-0.048	0.67	-0.160	0.11
Milk	-0.237	0.00	-0.175	0.02	0.008	0.94	-0.026	0.75
Fish	-0.043	0.64	0.113	0.18	-0.090	0.42	-0.025	0.77
Child age (yr)	1.674	0.00	1.789	0.00	-0.632	0.25	-1.461	0.00
Child age quadratic	-0.354	0.00	-0.373	0.00	0.154	0.26	0.277	0.02
Household head age	-0.012	0.50	-0.048	0.00	-0.041	0.04	-0.015	0.39
Household head age quadratic	0.000	0.78	0.000	0.01	0.000	0.03	0.000	0.44
Fever (1=yes)	-0.141	0.07	-0.061	0.40	-0.073	0.44	0.071	0.34
Diarrehea (1=yes)	-0.026	0.79	-0.040	0.65	-0.121	0.31	0.211	0.02
Rural residency (1=yes)	-0.072	0.39	0.041	0.60	-0.007	0.95	-0.148	0.07
Number of health posts	-0.022	0.00	-0.006	0.27	-0.036	0.00	0.002	0.68
Per capita expenditure (Rp)	-0.125	0.02	-0.178	0.00	-0.005	0.94	-0.035	0.47
Child sex (1=female)	-0.177	0.02	-0.217	0.00	-0.169	0.07	-0.274	0.00
Mother BMI	-0.014	0.16	0.004	0.69	-0.048	0.00	-0.012	0.20
Mother years of education	-0.041	0.00	-0.013	0.22	-0.017	0.22	-0.043	0.00
Child hemoglobin (g/dl)	-0.110	0.00	-0.094	0.01	-0.028	0.53	3.923	0.00
Mother hemoglobin (g/dl)							-0.153	0.02
_cons	0.664	0.33	0.773	0.24	2.322	0.01		
rho21	0.615	0.00		rho32	-0.112	0.06		
rho31	0.683	0.00		rho42	-0.051	0.45		
rho41	-0.092	0.20		rho43	0.002	0.98		
Number of obs	1374							
Wald chi2(67)	350.11							
Prob > chi2	0							
Log likelihood =	-2640.38							

Table 7: Animal source foods and continuous markers of nutrition (Results from SUR estimation)

Coefficient	WAZ	HAZ	WHZ	Hb
Mother years of education (yr)	0.0516***(0.0092)	0.0236** (0.011)	0.0533***(0.010)	0.0428***(0.012)
Mother BMI	0.0255***(0.0081)	0.000526 (0.010)	0.0361***(0.0090)	-0.00599(0.011)
Mother hemoglobin (g/dl)				0.184***(0.028)
Milk (1=yes)	0.163**(0.068)	0.252***(0.085)	0.0205(0.076)	0.168*(0.093)
Egg (1=yes)	0.0363(0.083)	-0.0158(0.10)	0.0286 (0.092)	0.118 (0.11)
Fish (1=yes)	-0.0827(0.074)	-0.0366(0.092)	-0.0852(0.082)	0.239**(0.10)
Meat or poultry (1=yes)	0.0354(0.068)	0.0957(0.085)	-0.00841(0.076)	0.00544(0.092)
Child age (yr)	-1.577***(0.41)	-1.095**(0.51)	-1.466***(0.46)	1.377**(0.56)
Child age quadratic	0.317***(0.10)	0.184(0.13)	0.357***(0.12)	-0.185(0.14)
Child sex (1=female)	0.0760(0.062)	0.175**(0.077)	0.0519(0.068)	0.360***(0.083)
Fever (1=yes)	-0.0127(0.063)	0.166**(0.079)	-0.145**(0.070)	-0.0286(0.085)
Diarrehea (1=yes)	-0.0104(0.077)	-0.133(0.096)	0.0933(0.085)	0.135(0.10)
Household head age	0.0404***(0.015)	0.00817(0.018)	0.0484***(0.016)	0.0331*(0.020)
Household head age squared	-0.000382***(0.00015)	0.0000111(0.00018)	-0.000521***(0.00016)	-0.000286(0.00020)
Per capita expenditure (Rp)	0.135***(0.042)	0.225***(0.052)	0.00920(0.046)	0.0331(0.056)
Rural residency (1=yes)	0.147**(0.069)	-0.0464(0.086)	0.230***(0.076)	0.128 (0.093)
Number of health posts	0.0225***(0.0046)	0.0136**(0.0057)	0.0216***(0.0051)	-0.000496(0.0062)
Constant	-2.180***	-1.801**	-1.814***	4.143***
	(0.57)	(0.71)	(0.63)	(0.82)
Observations	1289	1289	1289	1289
R-squared	0.14	0.10	0.07	0.14

Terms in parenthesis denote standard errors

Consumption of eggs at least four times in the previous week was negatively associated with diarrhea and eye infection morbidities after adjusting for other factors including consumption of vitamin A-rich fruits and vegetables and vitamin A supplementation (Table 8). Fish consumed seven or more times protected against eye infection. Boys were at higher risk for eye infection and diarrhea. Increasing age decreased the likelihood of fever and diarrhea. Sanitation factors (presence of a toilet) was strongly predictive of decreased prevelance of eye infection and diarrhea. In probit modeling for acute respiratory infection alone (Appendix 2), eggs consumed seven or more times in a week showed a significant protective effect (P=0.05).

Impact of HPAI on child nutrition

As discussed above the income effects on nutrition from a HPAI shock is likely to be insignificant given the structure of the household economy in the data. A very specialized type of shock i.e. one time, is moderate (in the range of 10-30% reduction), is concentrated in the poultry sector (in fact in our case even more restrictive to be only applicable to poultry farmers) is likely to have no significant impact on nutrition. Results in table 9 show the effect on z scores and haemoglobin concentration following a 30% income shock applied across the board to all poultry producers.

Even though in the aggregate the income shock to the poultry growers is not a significant factor for altering nutrition outcomes, few considerations apply. First, within the class of poultry growers there are likely to be some households for whom the share of poultry in income is high and these households and hence the child's nutrition is likely to be affected. Unfortunately, our dataset at hand does not allow making a distinction across households in terms of the importance of poultry.

Second, the poultry growers are only a segment of the chain and there are several others in the poultry supply chain who are likely to be affected by HPAI. Ignoring these households and children in those households is an underestimation that in some contexts could be very important.

Finally, the magnitude of shocks and their persistence will determine the overall impact on nutrition. The shocks as modeled here are transitory and hence only instantaneous impacts are assessed. In modeling consumption shocks there is an implicit assumption of shocks being persistent where changes in weekly consumption are used to ascertain effects on nutrition. Even being of identical magnitudes, persistent shocks will magnify the impact on nutrition through starker adjustment in consumption patterns.

The per capita expenditure affects nutrition in two plausible ways. First, PCE affects consumption of ASF and all other foods. Secondly, per capita expenditure has an independent effect on nutrition through channels like better quality of food, access to services and also awareness about correct nutrition choices. A drop in PCE affects consumption of all food products (including other ASF) and not only poultry products which is captured in simulations. Additionally, PCE has independent effects on nutrition outcomes such as through access to information and services and also on quality of food consumed. With persistent and greater magnitude of shocks the cumulative effect on nutrition will magnify.

Table 8: Determinants of morbidity outcomes

	Eye Infection			Fever			Diarrhea		
	Coef.	**Std. Err**	**P>|z|**	**Coef.**	**Std. Err**	**P>|z|**	**Coef.**	**Std. Err**	**P>|z|**
Egg 4+ times	-0.21766	0.132633	0.101	0.044878	0.069477	0.518	-0.21253	0.082105	0.01
Fish 7+ times	-0.34318	0.155224	0.027	0.074215	0.077492	0.338	0.140909	0.088585	0.112
Meat or poultry (1=any)	0.134528	0.120439	0.264	-0.10494	0.068056	0.123	-0.07813	0.077971	0.316
Milk (1=any)	-0.07634	0.111423	0.493	0.048091	0.065326	0.462	0.00365	0.073877	0.961
Papaya, mango, or carrot (1=any)	0.170418	0.124163	0.17	0.126522	0.06874	0.066	0.173857	0.078883	0.028
Vitamin A supplements (1=yes)	-0.12486	0.107271	0.244	-0.01226	0.062115	0.844	0.037095	0.070857	0.601
Child age (yr)	-0.09071	0.079413	0.253	-0.16979	0.044832	0	-0.10477	0.051705	0.043
Child sex (female=1)	-0.23269	0.108009	0.031	0.006592	0.06018	0.913	-0.1649	0.069163	0.017
Weight-for-age Z score	-0.08704	0.042707	0.042	-0.05242	0.023822	0.028	-0.02296	0.027669	0.407
Drinking water source in hh (1=yes)	0.13693	0.120263	0.255	0.055744	0.068291	0.414	0.170124	0.078294	0.03
Toilet (1=yes)	-0.38669	0.12117	0.001	-0.07264	0.0726	0.317	-0.27755	0.081021	0.001
Health posts in community	-0.01633	0.012139	0.179	-0.00459	0.00552	0.405	-0.00086	0.006303	0.892
Per capita expenditure (Rp)	5.84E-07	3.40E-07	0.086	-2.81E-07	2.24E-07	0.21	2.55E-07	2.54E-07	0.317
Household head age	0.010895	0.023834	0.648	-0.02404	0.013702	0.079	0.002787	0.01547	0.857
Household head age quadratic	-0.00012	0.000254	0.644	0.000213	0.000145	0.141	2.59E-05	0.000163	0.874
Rural residency (1=yes)	0.028883	0.123536	0.815	0.022923	0.067959	0.736	0.135792	0.078417	0.083
Number of obs	1769								
Wald chi2(67)	103.67								
Prob > chi2	0								
Log likelihood =	-2344.3324								

Table 9: Simulated effect of a 30% drop in per capita expenditure of poultry growers following a HPAI outbreak

Simulation Outcomes: Effect of 30% drop in pce for poultry owners

		Before		After		p25		p50		p75	
	N	**Mean**	**SD**	**Mean**	**SD**	**Before**	**After**	**Before**	**After**	**Before**	**After**
weight for age	476	-1.28	0.45	-1.33	0.43	-1.59	-1.63	-1.34	-1.37	-1.02	-1.08
length for age	476	-1.82	0.54	-1.89	0.51	-2.21	-2.27	-1.86	-1.92	-1.46	-1.53
weight for length	476	-0.46	0.36	-0.47	0.36	-0.70	-0.70	-0.48	-0.49	-0.26	-0.27
hemoglobin	476	10.49	0.61	10.49	0.61	10.09	10.09	10.51	10.51	10.91	10.91

[1] Drop in per capita expenditure also generates a drop in the probability of consumption as shown in the multivariate probit model.
P25, p50 and p75 denote the first, 2nd and third quartile (clubbed together) and the fourth quartile groups.

An alternative form of shock that HPAI can imply is through reduced consumption. Below results show the impact on children in households that are most likely to drop their consumption to zero following a change in preference as a result of HPAI outbreak.

The average treatment effects on the treated from propensity score matching have been reported below in table 10. In the propensity score matching the balancing property was satisfied for the following sets of variables, age of child, mother's education, per capita expenditure, sex of child, occupation of the household head, rural/urban status of the household to which the child belongs, age of the household head and morbidity variables such as diarrhea and fever. Higher orders of some variables were included to satisfy the balancing property.

Results show that for anemia, stunting and hemoglobin concentration these households that are most similar to households with no poultry consumption are likely to have adverse outcomes. The estimated Average Treatment Effect on the Treated are significant. In case of hemoglobin concentration, the difference between the treated and control group implies that because of poultry consumption per se the concentrations are higher on an average by 0.41g/dl. Since the children in these households are most likely to drop poultry consumption to zero, outcome in terms of hemoglobin concentration could worsen. In case of the dichotomous outcome variables (stunting and anemic) the probability that children will be stunted or anemic will likely be lower by 12 and 7% respectively relative to the control group.

Table 10: Average treatment effect of maintaining current consumption levels of poultry in face of HPAI shock

Variable	Sample	Treated	Controls	Difference	S.E.	*T-stat*
Stunted	ATT	0.443623	0.568751	-0.12513	0.04969	**-2.52**
Wasted	ATT	0.100739	0.096571	0.004168	0.033759	**0.12**
Underweight	ATT	0.271719	0.309734	-0.03802	0.044677	**-0.85**
Anemic	ATT	0.643253	0.715228	-0.07197	0.04088	**-1.76**
_zwei	ATT	-1.2965	-1.34336	0.046868	0.125571	**0.37**
_zlen	ATT	-1.83907	-1.99235	0.153279	0.158416	**0.97**
_zwfl	ATT	-0.46261	-0.37916	-0.08345	0.134551	**-0.62**
Hemoglobin concentration	ATT	10.5897	10.17418	0.415519	0.139714	**2.97**

Discussion

This study first identified the factors associated with ASF consumption and the importance of ASF consumption for nutrition and morbidity outcomes. Second, it demonstrated the potential nutrition impact of an HPAI shock via income and consumption channels. Household per capita expenditure was consistently predictive of both ASF consumption and nutrition outcomes. Other economic factors including value of household assets and age of household head, and mother's education level were also significantly related to ASF consumption. We showed that among children ages 12-36 mo, meat or poultry consumption in the last week showed a protective effect against anemia, while milk consumption in these children protected against stunting and being underweight. Intensity or number of times consumed in the previous week was more important for eggs and fish, than milk or meat/poultry. Children ages 6-36 mo who consumed eggs four or more times a week were significantly less likely to have diarrhea and eye infections, while consuming eggs 7 or more times was negatively associated with acute respiratory infection. Children consuming fish 7 or more times in a week were also less likely to have eye infection.

In terms of the HPAI shock on nutrition, we showed that up to a 30% reduction in PCE for households involved in poultry production would result in small declines in anthropometric Z scores and hemoglobin concentrations. If perceptions change towards consumption of poultry products then overall consumption of poultry products (purchased from the market or self produced) will show a drop. The benefit of positive consumption of poultry products by children in households similar to children consuming no poultry showed significant impact of the treatment (having positive consumption) on two nutrition outcomes variables i.e. stunting and anemia. Statistically significant average treatment effect on the treated was also obtained in case of hemoglobin concentration.

The strength of this analysis lies in its multivariate modeling using a system of equations for nutrition and ASF consumption outcomes - likely to have correlated, unobserved explanatory factors. This lends credibility to our findings about ASF consumption and nutrition by taking into account information not collected by the IFLS. We were able to look comprehensively at the relationship between household economics, ASF consumption, and nutrition outcomes. Poverty and food access has traditionally been considered an underlying, distal determinant of malnutrition. Our findings suggest it may be more closely associated with micronutrient nutrition in particular, via the ASF consumption pathway.

Few intervention studies have looked at ASF consumption in pre-school age children and nutrition outcomes, though observational studies have established a positive association (Marquis et al. 1997;Walker et al. 1991). Intervention trials in older children, however, have demonstrated the growth, body composition, cognition, and physical activity benefits of ASF consumption (Neumann et al. 2007).

Milk consumption was found to protect against both underweight and stunting classification. Because stunting or impaired linear growth is generally thought to occur over a longer period of time, this relationship can only be considered causal if these indicators served as a proxy for consumption earlier in the child's life. Milk was consumed more consistently across the age groups allowing for this possibility. Nonhuman, animal's milk is increasingly being shown to improve early childhood growth outcomes, potentially due to its content of insulin-like growth factor (IGF-1) as well as other critical macro- and micronutrients (Hoppe C., Molgaard, and Michaelsen 2006;Le and Butler 1999).

The presence or absence of eggs in the child's diet was not predictive of nutrition or morbidity outcomes, though when tested by frequency of consumption was associated with reduced likelihood of eye infection and diarrhea, when the child consumed eggs 4 more times in a week. There was also evidence for protection against acute respiratory infection, a more rare and serious event, when the child consumed eggs at a higher level – 7 or more times. Eggs are an excellent source of vitamin A, providing three or more times the concentration of bio-available retinol equivalents than other ASFs. Vitamin A deficiency is a public health problem in Indonesia and many supplementation and food-based strategies have been implemented in an effort to address this issue(De et al. 1999;De et al. 1998). Based on the previously established evidence that vitamin A nutrition protects eye health and reduces severity of diarrhea (Barreto et al. 1994;Black et al. 2008), our findings may be indicative of a vitamin A effect produced by frequency of egg consumption, with important implications in the HPAI scenario.

Anemia was found to be highly prevalent in this population, affecting two-thirds of the children ages 12-36 mo. Meat, poultry, and fish are good sources of heme-iron which is more readily absorbed in the body than non-heme iron sources found in plants; as well, milk and eggs can provide other nutrients associated with anemia such as vitamin B_{12}, riboflavin, or vitamin A. We found that if a child consumed any meat or poultry in the previous week, the likelihood of anemia was significantly reduced. Anemia may also arise from etiologies beyond inadequate iron intakes (Rastogi R. and Mathers 2000), including parasitic infections such as malaria, hookworm, and schistosomiasis, or from chronic conditions such as cancer, tuberculosis or HIV infection (World Health Organization (WHO) and Centers for Disease Control and Prevention (CDC) 2008). In Indonesia, helminth infections are common especially those caused by *Ascaris lumbricoides, Trichuris Trichiura*, and to a lesser extent hookworm. Malaria is also endemic in the country and could be contributing to anemia in these young children. Diarrhea was significantly, positively associated with anemia outcomes in our analyses, which may be indicative of intestinal infection or malabsorption or loss of micronutrients that protect against anemia.

Stunting was also prevalent affecting nearly one-third of the children, and underweight, 16%. These findings were consistent with studies characterizing anthropometry in Indonesia children. Another analysis of IFLS nutrition data that included children across a wider age range, showed a 35% prevalence of stunting among children 3-59 months, reduced from 41% in 1997 and 40% in 1993 surveys (Mani 2007). Nutrition data from the Indonesia Socioeconomic Household Surveys (SUSENAS) also showed reductions in weight-for-age or underweight malnutrition, from 37.7% in 1992 to 28.5% in 1999; the gains were largely derived from the period after one year of age (Waters et al. 2004). While the differences in nutritional status among different socio-economic strata were reduced in this period, maternal education and economic status (per-capita expenditures) remained strong predictors of WAZ, consistent with our findings. The SUSENAS data also showed males to be at greater risk for being underweight compared to females 1.27 OR ($P<0.001$) (Waters et al. 2004) similar to our study that showed being female protected against both stunting ($P=0.012$) and anemia ($P=0.05$).

Because of the close and often synergistic relationship between infectious disease and nutrition, it is critical that morbidity parameters such as diarrhea and respiratory illnesses be considered when modeling growth early in life (Scrimshaw, Taylor, and Gordon 1968;Shankar 2006). This study did not find significant associations for any of the morbidity covariates tested on nutrition outcomes, with the exception of diarrhea for anemia. This is likely due to problems related to measurement. The morbidity recall period is more optimally 14 days (Lanata, Quintanilla, and Verastegui 1994) as opposed to the one-month period used in IFLS. As well, IFLS collected information on prevalence of any diarrhea, for example, rather than incidence, number of episodes, or counts of days with diarrhea that is increasingly recognized as a useful nutrition-related indicator (Checkley et al. 2008;Morris et al. 1996). We did find that households reporting use of a toilet was protective against a child being underweight, and having a source of drinking water inside the home protected against stunting. These two indicators with known associations to diarrheal morbidity (Checkley et al. 2004) may have explained some variance in the nutrition outcomes related to infection. We also included number of health centres in the community of residence as a covariate representing access to health care and potentially influencing nutrition outcomes by mediating the morbidity effects. This covariate, however, was not significant perhaps due to the inclusion of rural vs urban residency.

Economic factors were demonstrated to play a role in determining both ASF consumption and the nutrition outcomes. Per capita expenditure, widely used as a reliable and sensitive marker of household wealth, was significant in every model at $P<0.05$ and in the anemia model at $P<0.10$. As well, the total value of household assets was found to be associated with child consumption of milk. Previous work has shown clear relationships between expenditure quintile and both consumption expenditure and quantity of non-staple foods, or "luxury" foods including ASF (Bouis and Pena, 1997). At the macroeconomic level, per capita meat is linearly related to gross domestic product (GDP) per capita (Speedy 2003). One study was recently conducted across five countries to specifically investigate the food security constraints at community, household, and individual levels on ASF consumption by children less than 3 years (Pachon et al. 2007).

The findings are consistent with the factors found to be associated with ASF consumption in this population. Poverty and animal health were among the community level availability constraints, while cost of ASF and limited livestock holdings at the household level were access barriers. At the individual level, care-giving practices, in particular, perception about giving ASF played an important role – a factor we were not able to investigate from the IFLS data. Our study was cross-sectional, and thus did not permit a time-dependent analysis for these effects. As well as the wealth effect on ASF consumption and nutrition, an inverse relationship may also have been possible, such that ASF consumption by household members contributed to greater productivity and wealth accumulation.

Given these results, some conclusions may be drawn with regards to the potential effects of HPAI in Indonesia and elsewhere on nutrition. In terms of the groups vulnerable to an HPAI shock, we provided evidence that if there were negative effects of HPAI on real income or assets, infants and young children would be at higher risk for stunting and underweight classification through reduced consumption of milk and meat or poultry. Own and cross-price elasticities, elsewhere determined high for poultry products in Indonesia (Hutasuhut et al. 2001;Sumiarto and Arifin 2008), were not calculated for this analysis, but may also play a role in this pathway. Populations who either depend on poultry and poultry products for their livelihood earnings or are affected by rising prices will be susceptible to reductions in household and young child ASF consumption.

In this study, families who reported consuming eggs that were self-produced showed a significant positive association with young child egg consumption (P=0.02) which will have relevance in situations where HPAI reduces poultry production. Autoconsumption of meat or poultry, however, was inversely related to child consumption as was belonging to a household in which members were engaged in agricultural employment. Children living in urban areas were more likely to consume ASF. Thus, poor, rural populations may be at higher risks of HPAI shock on nutrition through reductions in income, while poor, urban populations mainly through decreased poultry demand most likely through change in preferences.

There were a number of limitations with this study. To begin, ASF frequency of consumption served as the basis for the ASF analyses in relation to nutrition. This marker does not give information on *quantity* of foods consumed. In order to accurately capture any direct or dose-response effects of ASF on nutrition outcomes, a 24-hour recall would have been the preferred method of collecting dietary intakes (Gibson 2005). However, validation research has shown that ASF frequency of consumption especially when combined with vegetable and fruit group consumption can provide insight into micronutrient dietary adequacy, excluding consideration of iron nutrition (Working Group on Infant and Young Child Feeding Indicators 2007). Another limitation pertaining to the young child diet was that the IFLS survey did not provide comprehensive data on current breastfeeding status or patterns for the children, important determinants of early childhood growth. Dietary history questions only revealed the age at which food or water was introduced into the infant diet. Mothers were asked if they were currently breastfeeding, but not whether they were breastfeeding the child in question. The final important limitation we encountered was absence of sensitive micronutrient status markers.

We hypothesized that HPAI could have harmful consequences for micronutrient nutrition given that poultry and poultry products provide a rich bio-available source of micronutrients critical for growth, health and development. The anthropometric outcomes assessed can provide some indication of compromised micronutrient status, stunting, for example, in the case of zinc deficiency, but other biomarker and functional markers would have provided more precise information for vitamin A, iron, and zinc status. Finally, while IFLS covers 83% of the Indonesian population living in 13 of the 27 provinces, there were still many excluded populations living in more remote areas, likely poor and nutritionally compromised (Strauss et al. 2004a).

Despite these limitations, this study through its robust modeling, representative and large sample, and comprehensive factor analysis, provides evidence for the positive effects of ASF consumption on nutrition. Further, its findings regarding the determining power of household economic well-being (per capita expenditure, budget share, and value of assets) on ASF consumption suggest the potential for negative HPAI impacts on nutrition, particularly among vulnerable groups. Additional studies are justified, applying now more sensitive measures of both dietary intake and micronutrient status moving forward.

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Appendix 1. ASF Frequency and Nutrition Outcomes

Table A1: Multivariate probit for dichotomous nutrition outcomes with frequency of consumption of ASF

COEFFICIENT	Stunted	Wasted	Underwt	Anemic
Number of years of mother's education	**-0.0197****	**-0.0318****	**-0.0569*****	**-0.0504*****
	(-0.0098)	(-0.014)	-0.011	-0.011
Mother's hemoglobin concentration				**-0.151*****
				(-0.022)
Mother's body mass index	0.00684	**-0.0365*****	-0.00997	-0.00561
	(-0.0088)	(-0.013)	(-0.0093)	(-0.0098)
eggfreq	-0.00294	0.00338	-0.0134	0.0173
	(-0.015)	(-0.021)	(-0.016)	(-0.017)
fishfreq	**0.0301****	**-0.0421****	0.0104	0.0109
	(-0.013)	(-0.019)	(-0.014)	(-0.015)
meatpoultryfreq	**-0.0686*****	-0.0102	-0.0351	**-0.0504****
	(-0.023)	(-0.033)	(-0.027)	(-0.025)
milkfreq	-0.018	0.00604	-0.00358	0.00886
	(-0.011)	(-0.015)	(-0.012)	(-0.012)
Age of child	**1.475*****	**1.182****	**2.306*****	**-1.653*****
	(-0.43)	(-0.6)	(-0.48)	(-0.5)
Age of child squared	**-0.336*****	**-0.287***	**-0.523*****	**0.308****
	(-0.11)	(-0.15)	(-0.12)	(-0.12)
Sex of child	**-0.207*****	-0.106	**-0.119***	**-0.292*****
	(-0.066)	(-0.092)	(-0.072)	(-0.074)
fever	-0.0165	0.0163	-0.0631	0.0783
	(-0.067)	(-0.093)	(-0.073)	(-0.075)
diarrhea	-0.0482	**-0.223***	-0.0685	**0.178***
	(-0.083)	(-0.12)	(-0.09)	(-0.096)
Age of household head	**-0.0340****	-0.0338	-0.0188	-0.0156
	(-0.016)	(-0.021)	(-0.017)	(-0.018)
Age of household head squared	**0.000279***	**0.000378***	0.000122	0.000144
	(-0.00016)	(-0.0002)	(-0.00017)	(-0.00018)
Per capita expenditure	**-0.148*****	0.0347	**-0.107****	-0.0329
	(-0.047)	(-0.068)	(-0.053)	(-0.05)
rural	0.0892	-0.00906	-0.0938	-0.13
	(-0.072)	(-0.1)	(-0.078)	(-0.08)
Density of health posts in the community	0.00846	**-0.0652*****	**-0.0345*****	0.00744
	(-0.012)	(-0.018)	(-0.013)	(-0.013)
Constant	-0.355	-0.0524	-0.998	**5.672*****
	(-0.59)	(-0.82)	(-0.66)	(-0.77)
Observations	1534	1534	1534	1339

Appendix 2: Probit for Acute Respiratory Infection

	Coef.	Std. Err.	P>|z|
Egg 7+ times	-0.84176	0.425017	0.048
Fish 7+ times	-0.03937	0.206129	0.849
Meat or poultry (1=any)	-0.03757	0.186093	0.84
Milk (1=any)	0.274368	0.183791	0.135
Papaya, mango, or carrot (1=any)	0.159896	0.194064	0.41
vitamin A supplements (1=yes)	0.100896	0.169603	0.552
Child age (yr)	0.152057	0.121473	0.211
Child sex (female=1)	-0.3587	0.17161	0.037
Weight-for-age Z score	-0.21132	0.064487	0.001
Drinking water source in hh (1=yes)	0.093778	0.188336	0.619
Toilet (1=yes)	-0.16875	0.19251	0.381
Health posts in community	-0.00277	0.017484	0.874
Per capita expenditure (Rp)	6.65E-07	5.51E-07	0.227
Household head age	0.105719	0.047172	0.025
Household head age quadratic	-0.00108	0.000515	0.036
Rural residency (1=yes)	0.081761	0.186366	0.661
LR chi2(16)	36.48		
Prob>chi2	0.0025		
Log likelihood	-138.232		
Pseudo R2	0.1166		

Appendix 3: Simulation Results

Simulation Outcomes: Effect of 30% drop in pce for poultry owners

		Before		After		p25		p50		p75	
	N	**Mean**	**SD**	**Mean**	**SD**	**Before**	**After**	**Before**	**After**	**Before**	**After**
weight for age	476	-1.325	0.424	-1.371	0.407	-1.631	-1.659	-1.376	-1.413	-1.051	-1.103
length for age	476	-1.888	0.532	-1.956	0.510	-2.298	-2.342	-1.967	-2.025	-1.511	-1.568
weight for length	476	-0.461	0.344	-0.471	0.342	-0.678	-0.699	-0.470	-0.477	-0.267	-0.273
hemoglobin	476	10.519	0.601	10.517	0.604	10.133	10.119	10.586	10.584	10.921	10.917

[1] drop in per capita expenditure also generates a drop in the probability of consumption as shown in the multivariate probit model

Simulation Outcomes: Effect of 30% drop in pce for poultry owners

		Change				
	Mean	**SD**	**p25**	**p50**	**p75**	**N**
weight for age	-0.046	0.039	-0.026	-0.035	-0.055	476
length for age	-0.067	0.050	-0.038	-0.053	-0.083	476
weight for length	-0.010	0.015	-0.004	-0.007	-0.011	476
hemoglobin	-0.002	0.022	-0.001	-0.003	-0.007	476

[1] drop in per capita expenditure also generates a drop in the probability of consumption as shown in the multivariate probit model