Long-Term Impacts of an Unanticipated Risk Event

The 2007/08 Food Price Crisis and Child Growth
in Indonesia

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Abstract

Unanticipated spikes in food prices can increase malnutrition among the poor, with lasting consequences; however, livelihood strategies that include producing food for home consumption are expected to offer a measure of protection. Using anthropometric and consumption data from Indonesia collected before and after the 2007/08 food price crisis, this paper finds evidence of both effects. Based on standardized height and weight measures, the results indicate that soaring food prices had a significant and negative impact on child growth among non-farming households. A corresponding effect was undetectable for food-producing households. The results remain robust

when income effects from increased commercial sales and possible attritions through migration and fostering are considered. Further, local food price changes were uncorrelated with the share of non-farming village households and the initial average child nutrition status in the village, suggesting that the observed outcomes are directly attributable to market events and livelihood strategies. Interestingly, gender differences were not detected. The findings imply that the food price crises can have negative impacts on children, potentially leading to lifelong income inequality among those affected at a vulnerable stage of life.

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Long-term impacts of an unanticipated risk event : the 2007/08 food price crisis and child growth in Indonesia

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1. Introduction

Poor households build livelihood structures that include coping mechanisms to mitigate the many risks they face. Included are informal forms of insurance based on a willingness to help extended family members and neighbors in time of need with the expectation of receiving assistance when needed. In the absence of formal insurance and risk markets, informal mechanisms are crucial and can work well when risk events are idiosyncratic. However, informal insurance systems can fail when needed most in the face of a systemic risk event affecting all members of the informal insurance network. Governments can and do help prop up informal systems by responding to crises and by building all-purpose safety nets.

In rural areas, households often choose to produce much of their own food. This livelihood choice provides a measure of protection against a loss of other sources of income and can be especially effective in the face of rising food prices. However, the protection comes at a cost, since the strategy can obligate families to devote limited land and labor resources to activities and production technologies that are less profitable under normal circumstances. In turn, this makes it harder for families to generate higher incomes, accumulate wealth and human capital, and escape reinforcing poverty traps.

In this essay we focus on surging food prices, a cardinal risk that can undermine the capacity of poor households to meet minimal nutritional needs. Specifically, we examine potentially permanent effects of the food price crisis of 2007-08 on child nutrition intakes, distinguishing between food producers and non-producers. To bypass measurement problems inherent in consumption data, we use standardized child anthropometric nutrition-status measures such as the height-for-age and weight-for-age z scores, and we calculate local food price indices to take into account spatial differences in transmission of global price shocks and diet compositions. The analysis uses Indonesian household panel data collected in 2007 and 2010. The first round of 2007 was fielded from the second to third quarter, immediately before the initial food price run-up late in 2007. The follow-up survey was conducted in 2010 after the crisis had subsided. The timings offer us an ideal setting to assess the impact of food price spikes on child growth. The geographic coverage of the survey over seven provinces in five macro regional islands lets us take advantage of significant variations in village-level food price changes.

We find disheartening evidence that soaring prices had a significant and negative impact on child growth among non-farming households, despite government-backed support programs targeting the most vulnerable. At the same time, a corresponding effect on child growth was undetectable for food-producing households, suggesting that some measure of self-sufficiency remains a prudent course of action for poor rural households. The result remains robust when

income effects from increased commercial sales, as well as possible attritions through migration and fostering arrangements are considered. Further, local food price changes were uncorrelated with the share of non-farming village households and the initial average child nutrition status in the village, suggesting that observed outcomes are directly attributable to market events and livelihood strategies. Interestingly, gender differences were not detected. Our findings imply that the food price crises can have long-term impacts on child human capital formation, potentially fostering lifelong income inequality among those affected at an early and vulnerable stage of life. Policy implications are discussed in the concluding section.

2. Background

Between the summer of 2007 and June 2008, following decades of relative stability, global food prices spiked. On the heels of a six-month run-up in oil prices, wheat prices began to rise, surging 14 between May and June 2007. Maize prices increased 15 percent between December 2007 and January 2008. Rice prices, which had been climbing modestly during the summer, registered month-over-month increases of 21, 24 and 42 percent in February, March and April of 2008. Stocks relative to use had fallen for all three grains during the previous years, for a variety of reasons, including a strategic decision by China to draw down government stockpiles (Headey and Fan, 2008; Piesse and Thirtle, 2009). With inventories low, markets were positioned to react sharply to negative news (Larson, 2007). In the case of wheat, poor harvests in Ukraine and Australia were seen as triggering events, while, in the case of maize, the large diversion of US maize to mandated biofuel quotas was blamed (Mitchell 2008; Timmer, 2010, Headey, 2011). In the case of rice, researchers suggest that the crisis was largely driven by a series of over-reactive policy decisions, and that interventions meant to insulate domestic markets sometimes led to rounds of counter-productive hoarding and speculation (Slayton, 2009; Dawe, 2009; Timmer, 2010). Regardless, a contagion of decisions by large producers to restrict exports clearly exacerbated the crisis (Headey, 2011).³ From April 2007 to April 2008, the World Bank's Food Price Index rose by 67 percent, the associated Grain Index nearly doubled, and rice prices nearly tripled.

The scale and suddenness of the price increases unleashed widespread social and political unrest (Slayton, 2009; Bellemare, 2015). However, the sharp change in food prices played out differently among households, creating a continuum of outcomes, even among the poor (Swinnen, and Squicciarini, 2012.) In rural areas especially, households produce some or all of their own food, and this key aspect of rural livelihood strategies is thought to have been particularly important

³ Wheat exports from Argentina, Kazakhstan, the Russian Federation, and Ukraine were banned or otherwise restricted. China limited maize exports and levied new export taxes, as did Argentina. Cambodia, the Arab Republic of Egypt, India, and Vietnam restricted rice exports (Headey, 2011).

during the food price crises, since the cost of food produced and consumed at home is unaffected by changing market prices. In addition, households producing a surplus of food likely benefited from higher prices, as did households with livelihoods linked to agriculture. Consequently, poor rural smallholders are thought to be less vulnerable to food price spikes than the landless and urban poor (Ruel et al, 2010). Even so, the strategy comes at a high cost, since smallholders must often pass up more-profitable opportunities in order to generate their own food. What's more, households often choose to produce their food using traditional low-productivity farming methods. These choices can trap households on low-income paths and keep poor households poor (Binswanger and McIntire, 1987; Rosenzweig and Binswanger, 1993; Carter et al., 2007; Larson and Plessmann, 2009; Larson et al. 2016).

Nevertheless, because the poor devote 50-80 percent of their expenditure to food, and because many poor rural households are net buyers of food, the food crisis was thought to have increased poverty and malnutrition in both rural and urban areas (Pee et al., 2010). Results from a series of simulation models suggest these impacts were large. For example, de Hoyos and Medvedev (2011) estimate that the food crisis increased global poverty by more than 155 million people, and analysis by USDA (2009) suggests that the number of food insecure people rose by 80 million because of the crisis. The simulation models distinguished between food producing and food consuming households, and the results suggest some portion of poor net-producer households benefited from higher prices. For example, Ivanic and Martin, (2008) estimated that the crisis, on balance, decreased poverty rates in Pakistan and Vietnam. Still, most studies concluded that global net poverty rates increased as a result of the crisis, as did poverty rates in most developing countries, including Indonesia (McCulloch, 2008; Warr and Yusuf, 2014).

At the same time, it is important to keep in mind that the estimates of the impact of the crisis on poverty and food security come from model simulations, which necessarily rely on assumptions or a limited number of spatial observations about how global prices affected local market prices as well as stylized models of livelihood strategies. Because, in our study, we are looking directly at health outcomes attributable to the crisis, it is not necessary to fully quantify the full set of pathways connecting global food prices to child nutrient intake levels, but it is useful to understand how a common threat to food security can lead to a diffused set of outcomes.

2.1 Factors that mitigate the impact of off-shore food price increases

To start, price increases registered on traded commodities are not necessarily fully reflected in local prices. Most staple crops are produced and consumed locally; for example, only 7-8 percent of the world's rice enters formal trading routes (Timmer, 2010). And while there is strong evidence that the prices recorded at a country's borders reflect global markets, transportation and

transaction costs mute the impact of changes in international prices on local prices (Larson and Mundlak, 1992; Dawe and Maltoglou, 2014; Yang et al., 2015). Long-standing trade and food policies affect pass-through rates, too. However, in the case of the food-price crisis, a weakening US dollar and new interventions were important as well (Anderson, Ivanic and Martin, 2013).⁴

For example, in his study of seven large Asian countries during the crisis, Dawe (2009) found that, on average, exchange rate appreciations muted the impact of rising global prices by 18 percent, roughly \$32 per ton. Dawe also reports that the remaining price-wedge, attributable to markets and policies changed, such as tariffs, trading rules and consumption taxes were adjusted to insulate local markets. The net effect was to lower domestic prices, on average, by \$97 per ton, up from an average of \$16 a ton during the previous four years. In Indonesia, Dawe estimates that the insulating effect of the domestic policy-and-market wedge increased from \$13 to \$123 per ton, while the protection afforded by an appreciating rupiah declined slightly from \$20 to \$19 a ton.

Households that do face rising food prices can adjust, although the capacity to do so varies. Wealthier households are better able to smooth their intake of calories and essential nutrients by adjusting other expenditures, by drawing down savings and selling assets, and by borrowing (Morduch, 1995; Dercon, 2005; Kazianga and Udry, 2006; Carter and Lybbert, 2012). In contrast, poor households spend a disproportionate amount of their income on food generally and on staple crops in particular (Jensen and Manrique, 1998; Warr, 2005). Consequently, poor and near-poor households that purchase food are especially vulnerable to rising food prices.

In the face of incomplete markets for credit and insurance, poor households also develop alternative informal insurance mechanisms with family members and neighbors to mitigate the risks they face, lending support when asked and seeking assistance when they face difficulties of their own. Such arrangements can be effective when risks are idiosyncratic, but can also fail with dire consequences in the face of systemic events like the food crisis (Townsend, 1994; Larson, Anderson and Varangis, 2004; Skees et al., 2005). To counter this, governments and donors responded by bolstering existing food safety net programs, and launching feeding programs and other new initiatives aimed at helping the most vulnerable (Demeke, Pangrazio, and Maetz, 2008; Wodon and Zaman, 2010). By enhancing the capacity of households and informal insurance networks, these programs can mitigate malnutrition impacts (Coady, Grosh, and Hoddinott, 2004). When all else fails, households apportion limited food supplies among family members, where allocations are affected by family size, age and gender (Lanjouw and Ravallion, 1995; Aromolaran, 2004; Kumar and Quisumbing, 2013).

⁴When governments choose to intervene, the choice of instruments has distributional consequences (Poapongsakorn, 2010; Miranda et al., 2013).

2.2 Crises and nutrition outcomes

To the best of our knowledge, there are no peer-reviewed studies measuring the impact of the 2007/08 food price crisis on poverty, nutrition outcomes, or child health in Indonesia. However, there are a number of studies showing the links between child nutrition outcomes and fast-rising food prices from a decade earlier. The so-called “financial crises” of 1997/98 was in fact a broader event with three elements: a banking crisis, which led to a sharp depreciation of the rupiah, widespread political discord, which ended the 31-year-old presidency of Suharto, a severe drought and a series of wildfires, which led to food production shortfalls. Prices rose sharply, from January 1997 to October 1998. Rice prices increased by 195 percent, vegetable prices increased by 200 percent, dairy and egg prices increased by 117 percent, and fish and meat prices increased by 89 and 97 percent (Block et al., 2004). The price hikes for protein and vegetables raised particular concerns about micronutrient deficiencies, which have been linked to impaired cognitive development, lower educational attainment, impaired work capacity, increased morbidity and shortened lives (Block et al., 2008; Christian, 2010; Mani, 2012).

Nevertheless, studies of that episode suggest families managed to find ways to partly shield the diets of their children. For example, in a study limited to Java, Block et al. (2004) find no significant differences attributable to the 1997/98 crisis among children of either sex in a weight-for-age index; however, they do report an associated decline in maternal body mass, suggesting that mothers buffered the diets of their children by consuming less themselves.⁵ They also detect an increase in anemia for mothers and children, suggesting the crisis led to micronutrient deficits. Using a nationally representative data set, Strauss et al. also found no noticeable decline in weight-for-age from the crisis. Like Block et al. (2004), they did detect declines in hemoglobin concentrations, although the declines were only statistically significant among boys. Mani (2012) finds indications that the crisis reduced future height, but also finds evidence that younger children were able to partly recover. Estimating micronutrient demand elasticities before and after the 1997 crises, Skoufias, Tiwari and Zaman (2012) show that households managed to partially cope by significantly adjusting the composition of their diets.

Looking at the ongoing, rather than episodic effects of food price fluctuations in Indonesia, Yamauchi (2012) shows that the seasonality of rice prices explains birthweight, which subsequently affects height and weight. Low birthweight also negatively impacts schooling outcomes, such as the age at which children start school and the number of grade repetitions. The

⁵ It is important to keep in mind that, separate from the effects of specific economic events, many children in Indonesia remain at risk of malnutrition, despite decades of sustained economic growth and declining poverty rates (Strass et al., 2004).

research suggests that, over time, seasonal (presumably predictable) price movements combined with imperfectly timed fertilization have long-lasting impacts on human capital outcomes.

Before moving on, it is worth pointing out key differences between the 1997/98 and the 2007/08 crises, since much of what we know about the impact of food price spikes on childhood nutrition in Indonesia is based on the earlier event. As discussed, the 1997/98 crisis originated in the financial sector and moved quickly to the real economy. The Indonesian GDP declined by 13 percent in 1998 and remained flat in 1999. Food prices soared partly on a sharp devaluation of the rupiah and also because a drought and associated wildfires harmed domestic food production. The drought proved especially harmful to smallholder farmers (Bresciani et al., 2002). In contrast, the Indonesian economy remained robust during the 2007/08 crisis, as did the rupiah (Figure 2). Nationwide poverty levels fell in both rural and urban areas. Self-assessments of food insecurity improved during the period as well (Headey, 2010). Smallholder farmers, did not face weather-related problems. Agriculture generally benefited overall from higher international prices and grew as a share of GDP.

Nevertheless, our results suggest that a segment of society remained vulnerable to the significant price increases that did occur. The harshest consequences were felt by mostly urban households that were unable to produce a portion of their own food.

3. Conceptual and applied models

In the technical annex we develop a conceptual model, which we draw on here. The basic intuition behind the model is that households choose a livelihood strategy based on the resources they possess and the exogenous decision environment they face – that is, the many conditions beyond their control that shape the economic decisions they take. Included are decisions about how to marshal household resources to earn income, what to consume, how much to save and what ex ante steps to take to guard against potential risks. When a particular risk event occurs, households can make additional adjustments; however, these actions are constrained by past decisions and past risk outcomes. Broadly, households that produce some of their own food as part of their livelihood strategy are less threatened by rising food prices than those that do not; wealthier families and families protected through formal or informal safety nets are better able to adapt in ways that protect the health of their children.

This notion is summarized in the following livelihood constraint, developed in the technical annex: constraint: $w_1 = I(x; s) - c(s) - L(x; s) + w_0 \geq 0$, where income at the end of the period (w_1) depends on income producing activities (I), consumption (c), and losses from risk outcomes (L). Households use the assets they control (x) to earn income and to adjust their exposure to

potential risk events. Households make ex-ante plans based on what they think the elements of their decision environment (s^*) will look like, which is associated with the expected outcome w_1^* . Turning to the case at hand, one of the many factors affecting the household choice about future consumption and income activity choices is an expected food price, $p^* \in s^*$.

Assume that all goes as expected, except for an unanticipated increase in food prices, so that $p = p^* + \epsilon$, where $\epsilon > 0$. In this case, we can approximate the unanticipated change in wealth using the Taylor expansion: $w_1(p + \epsilon) \cong w(p^*) + w'(p^*)\epsilon + \frac{1}{2}w''(p^*)\epsilon^2$. Within this framework, an unanticipated change in food prices is expected to have up to three primary effects. For some households, the set of activities in $I(x^*)$ includes food production, which can be characterized by the expected profit function: $I_f^* = p^*y_f^* - wx^*$. All households consume food, where planned consumption is denoted by c_f^* . Food consumption, denoted by c_f , is determined via an expenditure function, with the following expected value: $c^* = e(p^*, w^*, \tilde{s}^*)$, where $c_f^* \in c^*$.⁶ For some households, formal safety nets and informal forms of insurance might soften the effects of the price hikes; however, there may be exacerbating outcomes as well. For example, family ties or implicit social contracts may oblige households to transfer resources to others, or income-earning activities with sunk costs might be abandoned as livelihood strategies shift. Consequently, the direct effects of the shock imply:

$$w_1(p + \epsilon) - w_0 \cong E[w_1 - w_0] + \left[y_f^* - \frac{\partial e}{\partial p} - \frac{\partial L}{\partial p} \right] \epsilon - \frac{1}{2} \left[\frac{\partial^2 e}{\partial p^2} + \frac{\partial^2 L}{\partial p^2} \right] \epsilon^2 \quad (1)$$

Recalling that the price shock is positive, the second term to the right of the approximation implies that food producers receive a windfall, $y_f^*\epsilon$ that other households do not; all households adjust their consumption, which contribute the (positive) amount, $\left[-\frac{\partial e}{\partial p} \right] \epsilon$ toward smoothing wealth.⁷ Also included is an adjustment via the loss function $\left[-\frac{\partial L}{\partial p} \right] \epsilon$, which has an indeterminate sign. The last term, which is unambiguously negative, relates to the stochastic nature of the livelihood problem. Here the intuition is that there is some positive probability that future events may push the household back on its planned trajectory; consequently, it is optimal to adjust less than fully during the current period

Child health outcomes are embodied in the consumption outcome. With this in mind, consider the critical value $\bar{c} > 0$ at which families cannot supply their children with adequate nutrition over

⁶ $\tilde{s}$ are the relevant elements of s in addition to p .

⁷ In practice, there are inherent differences among the households in any given survey sample that lead to differences in demand adjustments to price changes. Specifically, in the case of food producers, the relevant shadow price for produced food is likely different than the market price for food that is purchased or sold since transaction costs are incurred when markets are used. Consequently, food-producing households that are net sellers of food are likely to reduce their consumption of food by less than other households. This adds to the windfall producers gain from sales.

a given period. For each child, construct the follow health gap measure: $G(c) = \int_0^T [H(c^*) - H(c)]dt$. For children in household where $c > \bar{c}$, the health consequences of the gap will be negligible. Sadly, for some households planned consumption levels are inadequate under normal times, that is for some households, $c^* < \bar{c}$; however, when a food price spike occurs and realized consumption levels fall below planned consumption levels, the number of malnourished children is expected to rise as the number of households described by the inequality $c < \bar{c}$ increases. Said differently, food price shocks are expected to push the consumption levels of some vulnerable households with children at risk of malnourishment below adequate consumption levels.

As discussed, we do not directly observe consumption levels continuously over the duration of the food price shock. However, we do observe general household characteristics prior to the shock in 2007, including stores of wealth. We also observed household livelihood strategies in place prior to the shock, including whether producing food for home consumption was an element of that strategy. In addition, we have patchy information about other shocks experience by the household and household participation in formal safety-net programs. To see how these factors determined health outcomes we estimate the following applied model:

$$\Delta g_i = g_{it} - g_{it=0} \cong \Gamma(s_{ht=0}, w_0, z_{ht}) + e_{it} \quad (2)$$

where child i is a member of household h ; where $g_{it} = H(G, a)_{it} - H^B(a, \bar{c})$ measures the child's height against a standard benchmark for healthy children of a given age, a . The function Γ is meant to capture the consumption-resilience of the household in which child i resides. For reasons already discussed, we expect that wealth and a livelihood strategy that includes food production will increase resilience.

4. Empirical Strategy

4.1 Measurement, Identification and Specification

We use nutrition status of children, that is, the height-for-age and weight-for-age z scores, to measure child human capital as well as consumption/nutrition intake. Our identification relies on two settings. First, food price spikes were unanticipated, thus changes in food prices are treated as exogenous. Second, the household cannot quickly become a food producer. That is, we assume that time-hurdles and large fixed costs delay entry into food production.

To measure the average price changes, more specifically, price indices are constructed from food prices and quantities and calories consumed captured in two rounds before and after the 2007/08 food price crisis (i.e., 2007 and 2010). First, we compute the median price for each food commodity in each village. For each commodity, consumption is aggregated either in quantity or calorie by village to define the village-level consumption bundle. The price indices are computed

from the village-level median prices and the aggregate village-level consumption bundles. The Laspeyres index is an appropriate measure of price changes in our analysis since it uses the pre-crisis consumption bundles to weight food prices. However, we also check the results using the Paasche and Fischer indices.

We use the proportion of food consumption (in terms of calories) supported by own production as a livelihood strategy measure in the analysis. This measure captures the degree of self-protection against food price spikes that results from a pre-crisis decision about food self-sufficiency. The proportion can change over time as the household adjusts in response to food price changes by reallocating their labor and land; however, the fact that the 2007/08 food price crisis was likely a surprise encourages us to assume that the pre-crisis condition is uncorrelated with future food price changes. We provide evidence supporting this point later.

Based on (2) we use the following first-differenced applied model to measure the impact of food price spikes on child nutrition status:

$$\Delta g_{ijv} = \beta_1 \Delta P_v + \beta_2 k_j^0 \Delta P_v + X_{ijv}^0 B' + \Delta \varepsilon_{ijv} \quad (3)$$

where Δg_{ijv} is change in the anthropometric measure (weight or heights) of child i , in household j and village v , ΔP_v is the change in village-level price index (using either quantities or calories consumed), k_j^0 is either a continuous measure the proportion of consumed food calories supported by own production prior to the crisis, or (in some regressions) an indicator that takes the value of one if the proportion is below a threshold and zero otherwise. X_{ijv}^0 is a vector of initial individual, household and village characteristics, the child's age, gender, birthweight, initial household income, and the initial food self-sufficiency measure k_j^0 . The term $\Delta \varepsilon_{ijv}$ is a residual difference term, with a distribution centered on zero. The set of constants $[\beta_1, \beta_2, B]$ are estimated parameters. Actual calculations of ΔP_v and k_j^0 depend on the food commodities included. We cover (i) staples, (ii) fish, meat, tofu and tempe, (iii) beans (pulses), (iv) vegetables and fruits, and (v) milk and eggs.

A potential correlation between of ΔP_v and k_j^0 is a concern for the following reasons. First, the household may invest in child human capital to increase their resilience to possible food price spikes if they believe that such events are likely to occur. Second, consumption shocks can cause ΔP_v and k_j^0 to co-move. To minimize the risk of a possibly endogenous ΔP_v we use the Laspayres index based only on the 2007 consumption bundles, that is:⁸

$$P_{vt} = \frac{\sum_s p_{v,s,t} q_{v,s,0}}{\sum_s p_{v,s,0} q_{v,s,0}} (100) = \sum_s \frac{p_{v,s,t}}{p_{v,s,0}} w_{v,s} \quad (4)$$

⁸ The Paasche index uses the 2010 consumption bundles and thus represents a measure of the price surge's impact, after consumption patterns have adjusted. We return to this topic later in the paper.

where p and q are village-median prices and village-average consumption values for commodities $s = 1, 2, \dots, S$ for $t = 0 = 2007$ and $t = 1 = 2010$; the share weights are $w_{v,s} = 100 [p_{v,s,0} q_{v,s,0} / \sum_s p_{v,s,0} q_{v,s,0}]$. Note that, because the index uses weights determined prior to the price spike, it represents a village-level measure of the potential price shock prior to an adjustment of household expenditures, but accounting for protections from policies and market structures. This gives the measure an intuitive appeal, and should address endogeneity problems. This second point is ultimately an empirical issue, which we address later in the paper.⁹

4.2 Survey and Data

This section describes the survey data from Indonesia. The data come from panel household surveys in Indonesia, conducted jointly by Indonesian Center for Agricultural Socio Economic and Policy Studies, International Food Policy Research Institute and Japan International Cooperation Agency. First, the primary source of our data is the village and household surveys conducted in 2007 for 98 villages in 7 provinces (Lampung, Central Java, East Java, West Nusa Tenggara, South Sulawesi, North Sulawesi, and South Kalimantan) under the Japan Bank for International Cooperation (JBIC; currently JICA) Study of Effects of Infrastructure on Millennium Development Goals in Indonesia (IMDG-1). Figure 2 shows locations of surveyed villages. In 2010, the survey team revisited all the 98 sample villages to re-interview sample households and their splits. Out-migrants were also tracked through either direct or phone interviews.

Figure 3 about here

The 2007 survey was designed to overlap with villages covered in the 1994/95 PATANAS survey conducted by ICASEPS to build household panel data. The 1994/95 PATANAS survey was representative for Indonesia's major agro-climatic zones. In 2007, the ICASEPS/IFPRI team visited those villages to expand the scope of research as a general household survey. Thus, the IMDG-1 sample inherited the representation of major agro-climatic zones in the country. Moreover, the 2007 round added 51 new villages in the same areas (sample districts). These new villages were selected with the following criteria. Villages that had received relatively large amounts of government infrastructure projects during the period of 1995 to 2005 (mainly funded by either the Japan Bank for International Cooperation or the World Bank) were listed from the sample districts. The new villages were randomly sampled from the list. In the above procedure, the expanded sample also represents the major agro-climatic zones.

⁹ If households lower the quality of food commodities to reduce the food expenditure (therefore, a lower price per kilogram), the 2010 price is endogenous, resulting in potential underestimation of ΔP_v . However, the impact on calorie consumptions and our calorie-weighted index is minimal even in this case since the quality adjustment does not reduce calorie content in most commodities.

In the revisited original-sample villages in 2007, 20 households were resampled per village from the 1994/95 sample and the split households (defined below) were included. In the new villages, 24 households were sampled in each village. The 2010 survey followed the sample households in all 98 villages.

Between the surveys, some household members separated from the original 2007 households to start their own new households or to join other households. In the survey, a split household is defined as a new household in which (i) a member of the original household became the head of a new household, and (ii) the household resides in the same village. The above two conditions define split households in this study; household members who moved out of the original village or simply joined other households within the village are not called splits in the survey. From 2007 to 2010, 9.25% of the 2010 households were split households under the above definition. 12.97% of the sample individuals recorded as household members in 2007 migrated out, i.e., either moved out of their village or joined other households. The proportion is 11.82% once the group is restricted to those aged 20-55 in 2007.

Anthropometry data were collected in both 2007 and 2010. Child's height, weight, and his/her mother's weight were measured in the field. In addition, birthweight was recorded from official sources. However, the age coverage differs between the two rounds. In the 2007 round, children aged 0 to 6 were covered, and the 2010 round extended the age range to cover children aged up to 12. Figures 3a and 3b plot heights and weights over the two rounds, respectively, to show their dynamics. Following the standard procedure, we calculated the height-for-age z scores for children aged 0 to 12 and the weight-for-age z scores for children aged 0 to 10. In the panel analysis, we use the sample of children aged 0-6 in 2007 (thus, they are aged 3-9 in 2010).

The surveys collected consumption and expenditure data using the following formats. For food consumption, which is of our primary interest, respondents were asked to do a one-week recall to provide information, for each commodity, on quantity consumed and, if purchased, the price and how much of the total consumption is from own production or as gift. The 2007 round used different units of quantity but they were converted into kilogram when the data were processed. The 2010 round recorded quantities all in kilograms when households were interviewed (if necessary, converted in the field). The analysis uses price per kilogram. From the above data, we computed the proportion of calories produced by own production. Two measures were constructed to represent main foods and staple food (see Figures 4a and 4b, respectively). The main foods include (i) staple, (ii) fish, meat, tofu and tempe, (iii) beans (pulses), (iv) vegetables and fruits, and (v) milk and eggs.

Price indices were constructed from the food consumption data to understand the general trend of food price changes. We computed the Laspeyres and Paasche indices using the 2007 and

2010 quantities, respectively. First, Figure 5 compares the Laspeyres price indices using quantity-based and calorie-based weights. The calorie-based index is dominated by the quantity-based index but the two distributions are quite similar. Next, Figure 6a and 6b compare the Laspeyres and Paasche indices (quantity-based and calorie-based weights, respectively). By definition, the Laspeyres index captures the change in prices using their consumption patterns in 2007. In contrast, the Paasche index uses consumption patterns in 2010. The difference in the two indices is striking and shows the degree to which, on average, households were able to lessen the impact of price crisis by restructuring consumption.

Table 1 shows descriptive statistics of the Laspeyres price index by province using either quantities or calories as weights. For reference, Annex Figure A1 shows commodity-wise price changes measured by price 2010 divided by price 2007 and Annex Table A1 shows expenditure shares. It is clear that price increase is particularly large in vegetables. Table 1 point to two observations. First, the index is larger when weights are constructed from consumption quantities. This implies that households tend to consume more calories from foods that had smaller price increases at the subsequent period. Second, the means are quite similar across provinces, which indicates that, on average, price changes are uniform over the country. In the next section, we use within-province variations of food price changes in the child-growth regressions.

Table 2 shows food shares in value and calorie and Laspeyres index by food category. First, we observe that the consumption share of staples in calorie increased from 46 to 58 percent, while the figure in value slightly decreased from 28 to 25 percent. In contrast, the share decreased in calories in fish/meat/tofu/tempe and vegetables/fruits. Consistently, these categories experienced the largest price increase during the period. The table indicates a shift of consumption from nutritionally rich to nutritionally poor foods, pointing to an increased risk of micronutrient deficiencies.

Attrition is very small. In the estimation sample, attrition rates of children are 5.65% and 2.87% over the three years for the height-for-age z score and the weight-for-age z score, respectively. Below we perform attrition analysis that concludes that the main explanatory variables used in the main analysis are not significantly correlated with attritions (Table A2).¹⁰ In other words, food security strategies that involve child migration and fostering arrangements in response to increased food prices were not taken, thus not affecting our empirical results.

Village-level food price changes (Laspeyres) are also regressed on the proportion of food non-producers as well as the initial average child nutrition status in the village (Table 3). The results

¹⁰ In the weight z-score attrition equations, the asphalt road indicator and distance to provincial capital have significantly negative effects on attrition. However, since these two variables are controlled in the main outcome equations, we can conclude that they are not influential to our main findings.

confirm that local food price changes are uncorrelated with the initial livelihood strategies and child human capital, implying that at least in this restricted dimension, price changes are exogenous to the household. This finding is important since we can exclude the possibility of potential endogeneity of local food price changes. As shown later, a full specification that includes all explanatory variables (village-average) also confirms the result.

5. Empirical Results

This section summarizes the empirical results. As discussed, we use the Laspayres index of main food commodities as the measure of price changes, based on quantities and calories. Results using both constructions are presented in the following tables.

Table 4 shows the benchmark results on changes in the height-for-age z scores. Columns 1 and 2 presents the key results using quantity-based and calorie-based price indices, respectively. The specifications include the non-producer indicator that has the value of one if the proportion of main food consumption own produced is smaller than 0.035 and zero otherwise, the Laspeyres price index, their interaction term, age in months, age squared, male dummy, log of birthweight (kg), and province dummies. The results show a significant positive effect of the non-producer indicator and a negative effect of its interaction with the price index. The price index itself is not significant. Both results in quantity and calories are qualitatively similar. The non-producer households experienced higher child growth (without food price spikes) but they are more vulnerable to food price spikes than the producers, resulting in a significant reduction in child growth. Age has a significantly positive but convex effect. Children in Lumpung, East Java, NTB and North Sulawesi grew faster relative to those in Central Java.

Columns 3 and 4 include, as controls, household and village characteristics: the number of household members, household head's age (years), household income (labor earnings in 2007, not including transfer incomes and non-labor incomes), male head dummy, total asset values (residential and durable goods in 2007), income loss due to negative shocks during 2008-2010,¹¹ asphalt inter-village road indicator, distance to provincial capital (kilometers) and province dummies. Both household income and total assets are interacted with male dummy. Asphalt inter-village road indicator and distance to provincial capital are also interacted.

Both Columns 3 and 4 confirm a negative effect of the interaction of the non-producer indicator and the price index.¹² The price index itself is again not significant. Both results in quantity and

¹¹ There were 19 villages that reported crop failure. The effects of such incidents were included in this variable.

¹² In this sense, the substitution effect seems to overweigh the income effect among food non-producers, whereas the balance is not clear among food producers.

calories are qualitatively similar. Household income has a significantly positive effect but the effect is close to zero for males. The initial income effect is only significantly positive among females. The initial asset holding has a significantly positive effect only among males. Income loss due to negative shocks during 2008-2010 and its interaction with the initial asset holding were insignificant. The asphalt road indicator has a significantly positive effect only when the village is located far from the provincial capital.

Table 5 shows the results on changes in the weight-for-age z scores. Columns 1 and 2 presents the key results using quantity-based and calorie-based price indices, respectively. Interestingly, in the case of the weight z scores, we find a marginally significant positive effect in birthweight only. Price changes and the interaction with the non-producer indicator are insignificant. Columns 3 and 4 include household and village characteristics. First, the birthweight effect remains significantly positive (t values are much larger). Second, total asset values and income loss have significantly positive and negative effects, respectively. Third, interestingly, changes in the weight z score are larger in more remote areas (i.e., distant from provincial capital). Asphalt roads seem to increase child weights by improving spatial connectivity but the effect decreases in remote areas. The results in Tables 4 and 5 present a clear difference in the price spike impact between the height z-scores and the weight z-scores.¹³ Since height is a cumulative measure of human capital and weight can fluctuate responding to temporary shocks, we may conclude drawing upon the literature that the food price crisis could have a longer term impact on child human capital formation, as stunting at the early childhood is often a strong predictor of lower schooling and learning outcomes at later stages.¹⁴

Next we include the proportion of crop income in total household earnings¹⁵ and its interaction with Laspeyres index to explore possible income/wealth effects arising from food price spikes (Table 6). That is, farming households can potentially sell their production with a higher price (not necessarily directly consuming them) to increase income and consumption. Some estate-crop producers, largely located in outer-island communities, likely behave in this fashion. Interestingly, the proportion of crop income has a significant and positive effect on change in the height z score. That is, crop farming households had income gains during the period, which seemed to have a positive impact on child growth.¹⁶ In Column 1 using the quantity-based price index, price change

¹³ Seemingly Unrelated Regressions were also adopted to see changes in the inference, but the results are qualitatively the same as reported in the two tables.

¹⁴ We also estimated the two equations as a system (seemingly unrelated regressions), which confirmed that the results in Tables 3 and 4 are robust even after the cross-equation correlation is incorporated in inference.

¹⁵ Total household earnings do not include transfer and non-labor incomes.

¹⁶ Farm households who depend on crop incomes in the initial period have a large exposure to food price spikes. Whether the positive effect comes from the rise in income (the net position times the price change) or the subsequent change in quantity (supply response) remains not clear in this analysis.

also shows a significant and positive effect. Importantly, the main result on the negative impact of price spikes among food non-producers remains robust in Columns 1 and 2. Similar to the previous results, we have not seen any significant effects in the weight z score.

In our sample, farming practices differ between Java and outer Java islands. There are a large number of farmers who produce estate crops such as coconut, pineapple, cacao, coffee etc. in outer Java island provinces. In contrast, the majority of farm households produce rice and vegetables in Java provinces. Therefore, the above mentioned income/wealth effects are important in outer Java provinces. In Table 7, we use the sample only from two provinces in Java: Central and East Java. First, Columns 1 and 2 confirm that our key results on the height z scores are robust. Second, interestingly, we found that price spikes significantly decreased the weight z score in these two provinces. The linear effect of the price index is also significantly negative. In the environment where farming is more concentrated in staple and vegetable productions, the estimated impacts on child growth are larger with a substantial reduction in both height and weight among children in food non-producers.

Table 8 summarizes estimation results on potential heterogeneity by gender and age. The specifications include all the explanatory variables used in Table 3 (although they are not reported here). First, we do not detect a significant difference between boys and girls. This suggests that nutrition allocation between genders is relatively equal in our sample sites of Indonesia. Consistently, the direct effect of being male is always insignificant (Table 4). Second, we attempt to assess possible differences between the age 0-2 children and older children, since child development is most sensitive to nutrition intake at the critical stage during early childhood. Knowing this, parents may well try to protect the age 0-2 children more than older siblings. Nevertheless, we find no significant that difference by age group, implying that children are treated equally regardless of their ages.

Next we investigate whether the initial asset-holding and amounts of non-food expenditure, net remittance and public transfers in 2007 affect the price spike effect on child growth. All these initial conditions measure the degree to which households can buffer the adverse shocks from food price spikes. First, we checked potential heterogeneity by the initial asset holding with the hypothesis that wealthier households should be in a better position to buffer the negative effect of price spikes. The results are mixed here. In the height z scores, we have not seen any significant effects. However, in the case of the weight z scores, the interaction terms turn to be significantly positive. Interpretation requires a special care here. The direct effect of the initial assets is insignificant in this specification, which instead implies that the role of the initial asset holding is important among non-producers when local food price changes are larger.

Second, the roles of non-food expenditures, net remittance and public transfers in 2007 are examined. A large amount of non-food expenditures implies that households can potentially reallocate expenditures to food consumption to accommodate price spikes. On the other hand, if they were connected with others through remittances and/or already receiving public transfers before the crisis, it is easier for them to insure the adverse impact of price spikes with remittances (private transfers) and/or public transfers. The results show that their roles were rather at minimum to mitigate the price impact on child nutrition intake.¹⁷

The Paasche and Fischer indices are also used to compare with the Laspayres index (Table A3). The Paasche index uses the 2010 quantities (or calories) as weights, and the Fischer index is the square root of the product of the Laspayres and Paasche indices. Since the 2010 quantities (or calories) are part of the household's optimal responses to the food price crisis, the Paasche index is clearly endogenous. Similarly, for the Fischer index though the problem is milder. As presented in Figure 4, the Paasche index is generally smaller than the Laspayres index. As expected, Table 5 shows that the price spike effect using the Paasche index is insignificant. The results using the Fischer index is a mixture of the Laypeyres and Paasche results.

To sum, the above analysis confirmed potentially large negative impacts of food price spikes on child growth, measured by their heights, among food non-producers. Differences by gender or age were not found. The point estimate in Column 1 of Table 3 shows that an exposure to the sample average Laspeyres index of 245.82 (based on quantities) leads to a reduction of the height z-score by 1.9365. A similar exercise using calories in Column 2 of Table 3 shows a reduction of the height z-score by 1.7723. Changes in the height z-score by the above magnitude over 3 years are relatively large to induce a long term adverse impact on subsequent human capital outcomes unless those who were adversely affected have a chance to catch up later on. However, given that children in the non-producer households had the initial advantage of growing fast, our finding points to convergence in child growth between the two groups.

6. Conclusions

This paper examined the impact of food price spikes experienced during the 2007/08 food price crisis on child nutrition status using rural household panel data in Indonesia. The empirical results show that food price spikes had a significant negative impact on child growth, measured by the height z-score, among the food non-producers. There are a few important implications. First, food

¹⁷ Roles of formal safety net programs such as unconditional cash transfers and rice subsidy program are potentially important. However, the data cannot identify whether households were eligible in 2007. The (self-reported) eligibility status in 2010 is an endogenous outcome of changes in food price and household decision makings after 2007. For this reason, we have not included this variable in the above analysis.

production seems to work primarily as a self-protection livelihood strategy to safeguard household food consumption. Among food non-producers, inequality of child human capital increased between the severely affected and less affected areas.¹⁸

Second, the non-producers experienced longer-term negative impacts on child growth as the early childhood stage nutrition intake is a critical input determining subsequent human capital formation and outcomes. Interestingly, gender inequality is not observed in the context of Indonesia. The most vulnerable group of age 0-2 children was not protected, which implies that the intra-household allocation of food/nutrition consumptions seems not to be incorporating the dynamic impacts on child human capital formation and future earnings. Due to the short span of our panel data, however, the current study cannot assess the impact on schooling outcomes.

Another important implication of the above results is that available mitigation strategies, including public and private transfers, migration, fostering, consumption changes and nutrition reallocation can fail among non-food producers when food prices spike, even when governments and donors intervene with new programs. This results in a cohort of children born to poor families with an additionally reduced capacity to succeed.

In this context, some degree of self-sufficiency in food is a prudent livelihood choice for poor-but-landed households. Nevertheless, it is a choice that often precludes livelihoods that, on average, generate higher incomes, thereby locking households onto low-income pathways.

¹⁸ Positive response of unskilled labor wages to food price spikes is plausible in the medium to long run, which can reverse the price spike effect on poverty from positive to negative (Ivanic and Martin, 2014). However in their study, Indonesia is a country where the above reversal is not predicted.

Technical annex: derivation of the conceptual model

Formally, we start with the household's time-separable lifetime consumption planning problem developed in Larson and Plessmann (2009):

$$\begin{aligned} & \text{Max}_{c,x} E_t \int_{t_0}^{\infty} U(c_t; s_t) e^{-rt} \text{ subject to} \\ & dw = [I(x_t; s_t) - c_t(s_t) - L(x_t; s_t)]dt + \sigma[x_t, c_t, w_t; s_t]dv \\ & \text{and } w_{t_0} = w_0; s_{t_0} = s_0; w_{t_0} = w_0; w_t \geq 0; c_t \geq c_{\min} > 0 \end{aligned} \quad (\text{A.1})$$

where t denotes time; E denotes conditional expectations; U is an atemporal utility function; r is a discount rate; c represents consumption, which must equal or exceed the minimum positive value $c_{\min}$; s is a vector of additional exogenous state variables with an initial value of s_0 ; w represents wealth, bounded from below with an initial value of w_0 ; I is a net-income function that maps household activities, $y^i(x)$, to household income; L is an expected net loss function conditioned by the choice of activities, inputs, and a structure of contingent transfers provided by government programs, insurance or informal social obligations; v is a Wiener process with a zero mean and a unit variance; and $\sigma(x, c, w; s)$ is a scaling factor conditioned by the control (ex ante choice) variables and, possibly, other state variables. Expected net income losses are given by: $L(x, s) = \int_0^{R_0} \phi(R; x, s) dF(R)$ where $F(R)$ is the distribution function for random event R . In words, the household problem is to choose a consumption path that is conditioned by initial wealth and by generated income that is subject to loss. At any point in time, the on-going solution to the problem is expressed by a set of observed inputs, which themselves define a portfolio of activities. Further, the activities are related to inputs by particular applied technologies and associated loss functions that depend potentially on contingent transfers. Initial and conditioning state variables, such as available technology, relative prices, household characteristics and market conditions, frame the decisions that farmers take and thereby influence outcomes.

The problem is depicted as an infinite horizon to assumptions about intra-generational transfers. For the current period, when $t_0 = 0$, the problem can be expressed as:

$$rV(w; s) = \text{Max}_{x,c} E[U(c) + V_w(I - c - L) + \frac{1}{2} V_{ww} \sigma^2] \quad (\text{A.2})$$

where the first order conditions are:

$$\begin{aligned} \text{i)} & \quad V_w E(I_x - L_x) = 0 \\ \text{ii)} & \quad E(U_c) - V_w = 0 \\ \text{iii)} & \quad E(dw) = E(I - c - L) \\ \text{iv)} & \quad w_{t=0} = w_0 \end{aligned} \quad (\text{A.3})$$

To guarantee that the first-order conditions provide a maximum, V must be concave in w ; the solution values of w, c and x must be positive; and the transversality-at-infinity condition must hold.¹⁹

First-order conditions require that expected marginal gains and loss from additional input use are offsetting (condition i) and that the expected marginal utility from consumption equal the shadow-value of marginal wealth (condition ii). Expected wealth changes equal the expected savings or dis-savings (condition iii). In turn, the shadow value of marginal wealth depends in part on the distribution of risks. This relationship can be expressed by applying the envelope theorem to the value function and considering condition ii: $E[U_c] = V_w(w; s) = \frac{1}{r}(V_{ww}\dot{w} + \frac{1}{2}V_{www}\sigma^2)$.

The dual condition states that the expected utility from marginal consumption must also equal the present value of the foregone stream of future wealth. When $V_{www} \geq 0$ the value of the foregone income stream includes a “precautionary” value of wealth based partly on the variability of wealth outcomes. Conditions iii) and iv) restate constraints on the optimum. Together, the conditions state formally the common sense notion that the solution to one among several household activities will be conditioned by constraints on the overall household problem. Operationally, this means that applied models designed to measure the efficiency of a particular activity such as rice farming, should include, as state variables, the larger set of variables that define the household problem.

Food price risks

Our empirical model examines how food price shock plays out in the context of the household livelihood problem developed above. In particular, consider the livelihood constraint: $w_1 = I(x) - c(s) - L(x) + w_0 \geq 0$. Looking ahead, the first-order-condition 3.iii) states that the household holds the following expectation: $E[w_1^* - w_0] = I(x^*) - c^* - L(x^*)$, where $[x^*, c^*; s_0]$ is the solution value of equation 1. Turning to the case at hand, one of the many factors affecting the household choice about future consumption and income activity choices is an expected food price, $p^* \in s_0$.

Assume that all goes as expected, except for an unanticipated increase in food prices, so that $p = p^* + \epsilon$. In this case, we can approximate the unanticipated change in wealth using the Taylor expansion: $w_1(p + \epsilon) \cong w(p^*) + w'(p^*)\epsilon + \frac{1}{2}w''(p^*)\epsilon^2$. Within this framework, an unanticipated change in food prices is expected to have up to three primary effects. For some households, the set of activities in $I(x^*)$ includes food production, which can be characterized by the expected profit function: $I_f^* = p^*y_f^* - wx^*$. All households consume food, where planned consumption is denoted by c_f^* . Food consumption, denoted by c_f , is determined via an expenditure function, with the following

¹⁹ The condition guarantees that the ending-value of the problem diminishes with the length of the horizon. See Malliaris and Brock (1982) for a discussion of stochastic control models and the transversality condition.

expected value: $c^* = e(p^*, w^*)$, where $c_f^* \in c^*$. For some households, formal safety nets and informal forms of insurance might soften the effects of the price hikes; however, there may be exacerbating outcomes as well. For example, family ties or implicit social contracts may oblige households to transfer resources to others, or income-earning activities with sunk costs might be abandoned as livelihood strategies shift.

For simplicity's sake, we assume that food production decisions and outcomes occur prior to the price shock. Consequently, the direct effects of the shock imply²⁰:

$$w_1(p + \epsilon) - w_0 \cong E[w_1 - w_0] + \left[y_f^* - \frac{\partial e}{\partial p} - \frac{\partial L}{\partial p} \right] \epsilon - \frac{1}{2} \left[\frac{\partial^2 e}{\partial p^2} + \frac{\partial^2 L}{\partial p^2} \right] \epsilon^2 \quad (\text{A.4})$$

Recalling that the price shock is positive, the second term to the right of the approximation implies that food producers receive a windfall, $y_f^* \epsilon$ that other households do not; all households adjust their consumption, which contribute the (positive) amount, $\left[-\frac{\partial e}{\partial p} \epsilon \right]$ toward smoothing wealth.²¹ Also included is an adjustment via the loss function $\left[-\frac{\partial L}{\partial p} \epsilon \right]$, which has an indeterminate sign. The last term, which is unambiguously negative, relates to the stochastic nature of the livelihood problem. Here the intuition is that there is some positive probability that future events may push the household back on its planned trajectory; consequently, it is optimal to adjust less than fully during the current period.

Price shocks and child nutrition

When shocks occur, the inability of the household to maintain planned levels of consumption and savings has many implications. One of the longest lasting effects comes from the inability of families to adequately nourish their children.

Consider the level of food consumption planned by parents for the children, $c_{fN}^* \in c_f^* \in c^*$. For children, planned consumption levels imply a level of physical health that shows up in measurable ways, most obviously in terms of height and weight. There are large variations among well-nourished children, however when consumption levels are inadequate to maintain a child's health, permanent gaps appear among cohorts of nourished and malnourished children.

More formally, consider the critical value $\bar{c} > 0$ at which families cannot supply their children with adequate nutrition over a given period. For each child, construct the follow health gap

²⁰ We ignore second-order market effects, for example, the impact of the food price shock on wages or other prices.

²¹ In practice, there are inherent differences among the households in any given survey sample that lead to differences in demand adjustments to price changes. Specifically, in the case of food producers, the relevant shadow price for produced food is likely different than the market price for food that is purchased or sold since transaction costs are incurred when markets are used. Consequently, food-producing households that are net sellers of food are likely to reduce their consumption of food by less than other households. This adds to the windfall producers gain from sales.

measure: $G(c) = \int_0^T [H(c^*) - H(c)]dt$. For children in household where $c > \bar{c}$, the gap will be negligible. Sadly, for some households planned consumption levels are inadequate, that is for some households, $c^* < \bar{c}$; however, when a food price spike occurs and realized consumption levels fall below planned consumption levels, the number of malnourished children is expected to rise as the number of households described by the inequality $c < \bar{c}$ increases. Said differently, food price shocks are expected to push the consumption levels of some vulnerable households with children at risk of malnourishment below adequate consumption levels.

The degree to which shocks affect consumption is summarized in the solutions to the household problem. To see this, rearrange the livelihood constraint derived earlier from 3.iii to derive the general function: $c^* = \Theta(I^*, L^*, w^*; s_0, w_0)$, so that:

$$c^* - c = \Delta c = \dot{\Theta}(\Delta I, \Delta L, \Delta w; s_0, w_0, s) = \phi(w_0, \Delta s) \quad (\text{A.5})$$

In the case of a food price shock, the unanticipated component of the food price change leads to a change in consumption that depends on the households' livelihood structure, including formal safety nets and informal contingent obligations, which are accounted for in the loss function L , and the family's capacity to draw on stored wealth.²² The change in food consumption for the family and for children will also depend on a general reallocation of consumption, as $\Delta c_{fn} \in \Delta c_f \in \Delta c$.

As discussed, we do not directly observe consumption levels continuously over the duration of the food price shock. However, we do observe general household characteristics prior to the shock in 2007, including stores of wealth. We also observed household livelihood strategies in place prior to the shock, including whether producing food for home consumption was an element of that strategy. In addition, we have patchy information about other shocks experience by the household. To see how these factors determined health outcomes we estimate the following model:

$$\Delta g_i = g_{it} - g_{it=0} \cong \Gamma(s_{ht=0}, w_0, z_{ht}) + e_{it} \quad (\text{A.6})$$

where child i is a member of household h ; where $g_{it} = H(G, a)_{it} - H^B(a, \bar{c})$ measures the child's height against a standard benchmark for healthy children of a given age, a . The function Γ is meant to capture the consumption-resilience of the household in which child i resides. For reasons already discussed, we expect that wealth and a livelihood strategy that includes food production will increase resilience.

²² Unexpected transfers, such as transfers from unanticipated relief programs, are also accommodated in ΔL .

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Figure 1: International commodity prices

Note: The crude oil is the average price of Brent, Dubai and West Texas Intermediate, equally weighed; Maize (US), no. 2, yellow, f.o.b. US Gulf ports; wheat (US), no. 1, hard red winter, ordinary protein, export price delivered at the US Gulf port for prompt or 30 days shipment; Rice (Thailand), 100% broken, A.1 Super, government standard, f.o.b. Bangkok. Source: World Bank Commodity Price Data (2016)

Figure 2: Poverty and economic growth in Indonesia, 2005-2010

Source: World Bank Development Indicators (2016)

Figure 3: Locations of surveyed villages

Figure 4: Heights and weights in 2007 and 2010

Figure 5: Proportion of food commodities own produced

Figure 6: Laspayres price index – Comparison between quantity and calorie

Figure 6a Price change – Laspayres and Paasche indices based on quantities

Figure 6b Price change – Laspayres and Paasche indices based on calories

Table 1 Laspeyres index by province

Villages	Obs.	Mean	Std. Dev.	Min	Max
<u>Lampung</u>					
Quantity based	16	260.09	45.90	184.23	343.14
Calorie based	16	231.6	41.2	150.4	297.3
<u>Central Java</u>					
Quantity based	12	252.8	83.4	162.8	479.9
Calorie based	12	243.2	80.1	161.5	472.2
<u>East Java</u>					
Quantity based	11	258.0	38.4	219.4	352.5
Calorie based	11	233.8	23.0	204.4	272.7
<u>NTB</u>					
Quantity based	13	228.1	56.7	152.8	324.2
Calorie based	13	231.2	71.1	163.2	389.3
<u>South Kalimantan</u>					
Quantity based	16	272.0	30.5	242.6	336.7
Calorie based	16	253.3	27.1	209.3	301.1
<u>North Sulawesi</u>					
Quantity based	12	224.0	38.3	180.7	289.1
Calorie based	12	191.0	25.9	157.7	244.6
<u>South Sulawesi</u>					
Quantity based	18	225.1	41.4	155.9	346.9
Calorie based	18	207.2	38.7	151.3	315.3

Table 2 Food shares and price change by food category

Food Category	Villages	2007	2010
<u>Staple</u>			
Laspeyres (quantity)	98	100.00	134.65
Value-based share	98	0.28	0.25
Calorie-based share	98	0.46	0.58
<u>Fish/meat/tofu/tempe</u>			
Laspeyres (quantity)	98	100.00	186.14
Value-based share	98	0.22	0.19
Calorie-based share	98	0.06	0.05
<u>Beans (pulses)</u>			
Laspeyres (quantity)	93	100.00	171.86
Value-based share	98	0.01	0.01
Calorie-based share	98	0.02	0.02
<u>Vegetables/fruits</u>			
Laspeyres (quantity)	98	100.00	282.98
Value-based share	98	0.11	0.12
Calorie-based share	98	0.07	0.04
<u>Milk/egg</u>			
Laspeyres (quantity)	98	100.00	176.43
Value-based share	98	0.05	0.06
Calorie-based share	98	0.02	0.02

Table 3 The initial conditions and local food price changes

Dependent variable: Laspeyres index				
Weights:	Quantity	Calorie	Quantity	Calorie
Proportion of food non-producers	-22.94 (1.28)	-20.83 (0.97)	1.51 (0.08)	4.97 (0.27)
Average height z score			7.85 (1.21)	2.93 (0.46)
Average weight z score			0.87 (0.10)	0.24 (0.03)
Number of observations	98	98	98	98
R sq (between)	0.017	0.010	0.018	0.003

Note: Numbers in parentheses are absolute t values. Full specifications that include all the explanatory variables used in the following analyses also show their insignificant effects on village-level price changes.

Table 4 Impacts of price change on the height-for-age z score

Dependent variable: Change in height z-score				
Sample: Age 0-6 in 2007				
Index type: Laspayres				
Weights:	Quantity	Calorie	Quantity	Calorie
Price change (index/village)	0.0041 (1.10)	0.0042 (1.01)	0.0027 (0.84)	0.0022 (0.59)
Price change (index/village) * Non-producer	-0.0075 (4.00)	-0.0071 (3.19)	-0.0079 (3.73)	-0.0072 (2.56)
Age 2007 (months)	0.0642 (2.61)	0.0645 (2.63)	0.0733 (3.52)	0.0737 (3.64)
Age 2007 squared	-0.0007 (2.15)	-0.0007 (2.16)	-0.0009 (2.76)	-0.0009 (2.84)
Male	-0.1148 (0.59)	-0.1158 (0.60)	-0.2592 (1.33)	-0.2624 (1.38)
Log of birthweight (kg)	0.3616 (0.81)	0.3222 (0.70)	0.3295 (0.75)	0.2968 (0.67)
Non-producer	1.6150 (3.40)	1.3860 (2.83)	1.7955 (3.11)	1.5084 (2.16)
Household size 2007			-0.0418 (1.18)	-0.0398 (1.04)
Head male 2007			-0.4211 (0.94)	-0.4075 (0.90)
Head age 2007			0.0065 (0.98)	0.0056 (0.79)
Household income 2007			3.48E-09 (7.50)	3.47E-09 (6.82)
Household income 2007 * Male			-4.52E-09 (10.58)	-4.53E-09 (9.55)
Total assets 2007			1.03E-10 (0.10)	1.12E-10 (0.11)
Total assets 2007 * Male			3.73E-09 (3.06)	3.73E-09 (3.01)
Income loss			2.23E-08 (1.17)	2.42E-08 (1.26)
Income loss * Total assets 2007			-4.15E-17 (1.41)	-4.44E-17 (1.58)
Asphalt road			-0.1031 (0.48)	-0.0416 (0.18)
Distance to provincial capital			0.0001 (0.14)	0.0003 (0.43)
Asphalt * Distance			0.0020 (2.96)	0.0017 (2.54)
Province dummies	yes	yes	yes	yes
Number of observations	578	578	551	551
R squared	0.0632	0.0623	0.1203	0.1185

Note: Numbers in parentheses are absolute t values using robust standard errors with province clusters

Table 5 Impacts of price change on the weight-for-age z score

Dependent variable: Change in weight z score				
Sample: Age 0-6 in 2007				
Price change: Laspayres				
Weights:	Quantity	Calorie	Quantity	Calorie
Price change (index/village)	0.0003 (0.22)	0.0003 (0.20)	-0.0005 (0.36)	-0.0003 (0.15)
Price change (index/village) * Non-producer	-0.0009 (0.37)	-0.0012 (0.47)	-0.0005 (0.20)	-0.0015 (0.65)
Age 2007 (months)	0.0127 (0.94)	0.0127 (0.93)	0.0128 (0.78)	0.0130 (0.80)
Age 2007 squared	3.01E-06 (0.01)	1.71E-06 (0.10)	4.77E-06 (0.02)	3.81E-07 (0.00)
Male	0.0374 (0.26)	0.0359 (0.25)	0.0907 (0.51)	0.0854 (0.49)
Log of birthweight (kg)	0.3930 (1.74)	0.3934 (1.79)	0.2634 (2.21)	0.2741 (2.60)
Non-producer	0.3047 (0.56)	0.3691 (0.62)	0.2307 (0.37)	0.4497 (0.82)
Household size 2007			0.0100 (0.33)	0.0104 (0.34)
Head male 2007			-0.2265 (0.83)	-0.2373 (0.84)
Head age 2007			-0.0037 (2.39)	-0.0039 (2.46)
Household income 2007			9.36E-10 (0.53)	9.40E-10 (0.54)
Household income 2007 * Male			-2.04E-09 (1.17)	-2.04E-09 (1.18)
Total assets 2007			1.48E-09 (2.12)	1.44E-09 (2.15)
Total assets 2007 * Male			-3.39E-10 (0.24)	-3.02E-10 (0.22)
Income loss			-1.08E-08 (2.55)	-1.00E-08 (2.36)
Income loss * Total assets 2007			1.71E-17 (1.47)	1.63E-17 (1.40)
Asphalt road			0.2992 (1.71)	0.3091 (1.75)
Distance to provincial capital			0.002 (3.45)	0.002 (3.60)
Asphalt * Distance			-0.0013 (2.19)	-0.0013 (2.24)
Province dummies	yes	yes	yes	yes
Number of observations	603	603	575	575
R squared	0.0651	0.0652	0.098	0.0986

Note: Numbers in parentheses are absolute t values using robust standard errors with province clusters

Table 6 Effects of crop income

Dependent variable:	Change in height z-score		Change in weight z-score	
Sample: Age 0-6 in 2007				
Price change: Laspayres				
Weights for Laspayres index:	Quantity	Calorie	Quantity	Calorie
Price change (index/village)	0.0049 (2.22)	0.0037 (1.37)	-0.0018 (0.83)	-0.0025 (0.84)
Price change (index/village) * Non-producer	-0.0093 (3.86)	-0.0081 (2.82)	0.0002 (0.06)	-0.0005 (0.17)
Proportion of crop income 2007	1.9767 (2.07)	1.4289 (1.87)	-0.944 (0.73)	-1.3063 (1.04)
Price change (index/village) * Prop of crop income 2007	-0.0065 (1.44)	-0.0046 (1.12)	0.0038 (0.67)	0.0058 (0.93)
All other explanatory variables included:	yes	yes	yes	yes
Number of observations	551	551	575	575
R squared	0.1284	0.1247	0.1001	0.1031

Numbers in parentheses are absolute t values using robust standard errors with province clusters. All other explanatory variables are included in the above specifications (see Table 3)

Table 7 Java island sample

Dependent variable:	Change in height z score		Change in weight z-score	
Sample: Age 0-6 in 2007				
Price change: Laspayres				
Weights for Laspayres index:	Quantity	Calorie	Quantity	Calorie
Price change (index/village)	-0.0037 (0.67)	-0.0043 (0.74)	-0.0026 (1.67)	-0.0031 (2.34)
Price change (index/village) * Non-producer	-0.0112 (2.16)	-0.0126 (5.50)	-0.0062 (2.03)	-0.0057 (2.80)
All other explanatory variables being included:	yes	yes	yes	yes
Number of observations	112	112	114	114
R squared	0.2255	0.2349	0.23	0.2299

Numbers in parentheses are absolute t values using robust standard errors with province clusters. All other explanatory variables are included in the above specifications (see Table 3)

Table 8 Heterogeneity by gender and age

Dependent variable	Change in height z score		Change in weight z-score	
Sample: Age 0-6 in 2007				
Price change: Laspayres				
Weights for Laspayres index:	Quantity	Calorie	Quantity	Calorie
Gender regression				
Price change (index/village) * Non-producer	-0.0077 (3.83)	-0.0071 (2.59)	-0.0014 (0.61)	-0.0027 (1.03)
Price change (index/village) * Non-producer * Male	0.0002 (0.26)	0.0004 (0.41)	0.0011 (1.54)	0.0011 (1.33)
Number of observations	551	551	575	575
R squared	0.1215	0.1200	0.1038	0.1042
Age regression				
Price change (index/village) * Non-producer	-0.0077 (4.08)	-0.0070 (2.87)	-0.0005 (0.19)	-0.0015 (0.64)
Price change (index/village) * Non-producer * Age < 24 months	-0.0002 (0.10)	-0.0002 (0.08)	0.0001 (0.14)	0.0002 (0.19)
Number of observations	551	551	575	575
R squared	0.1213	0.1196	0.0985	0.0991

Numbers in parentheses are absolute t values using robust standard errors with province clusters. All other explanatory variables are included in the above specifications (see Table 3)

Table 9 Asset, non-food expenditures, remittance and public transfers

Dependent variable:	Change in height z score		Change in weight z-score	
Sample: Age 0-6 in 2007				
Price change: Laspayres				
Weights for Laspayres index:	Quantity	Calorie	Quantity	Calorie
Asset regression				
Price change (index/village) * Non-producer	-0.0081 (3.98)	-0.0075 (2.78)	-0.0009 (0.32)	-0.0020 (0.88)
Price change (index/village) * Non-producer * Total assets 2007	6.54E-12 (0.61)	7.69E-12 (0.86)	1.15E-11 (2.04)	1.21E-11 (2.30)
Number of observations	551	551	575	575
R squared	0.1208	0.1192	0.1009	0.1016
Non-food expenditure regression				
Price change (index/village) * Non-producer	-0.0076 (3.43)	-0.0068 (2.47)	-0.0009 (0.33)	-0.0021 (0.90)
Price change (index/village) * Non-producer * Non-food exp 2007	-1.53E-10 (1.39)	-1.57E-10 (1.32)	1.74E+10 (2.89)	1.84E-10 (2.87)
Number of observations	551	551	575	575
R squared	0.1242	0.1221	0.1070	0.1074
Remittance regression				
Price change (index/village) * Non-producer	-0.0079 -3.66	-0.0072 -2.51	-0.0005 -0.17	-0.0015 -0.6
Price change (index/village) * Non-producer * Net remittance 2007	9.52E-11 (0.56)	8.93E-11 (0.53)	2.39E-10 (1.29)	2.43E-10 (1.33)
Number of observations	551	551	575	575
R squared	0.1206	0.1188	0.1012	0.1018
Public transfer regression				
Price change (index/village) * Non-producer	-0.0079 (3.72)	-0.0072 (2.58)	-0.0005 (0.21)	-0.0015 (0.60)
Price change (index/village) * Non-producer * Public transfers 2007	2.28E-10 -0.1500	1.01E-10 -0.9000	-1.47E-09 -1.21	-1.20E-09 -0.94
Number of observations	551	551	575	575
R squared	0.1203	0.1186	0.0981	0.0987

Numbers in parentheses are absolute t values using robust standard errors with province clusters. All other explanatory variables are included in the above specifications (see Table 3)

Annex figures and tables

Figure A1 Price increase by category: Price 2010 / Price 2007²³

²³ In Figure A1, we omit outliers defined if price 2010 are more than or equal to 10 times larger than price 2007.

Table A1 Expenditure shares

Province	Staple crops	Fish/meat/tofu/tempe	Pulses	Vegetable/fruit	Milk/egg
Lampung	0.280	0.236	0.012	0.101	0.046
Central Java	0.283	0.148	0.011	0.105	0.051
East Java	0.252	0.208	0.019	0.112	0.053
NTB	0.339	0.219	0.014	0.104	0.043
South Kalimantan	0.257	0.264	0.010	0.097	0.062
North Sulawesi	0.236	0.271	0.017	0.114	0.071
South Sulawesi	0.328	0.185	0.013	0.107	0.056

Note: Means of village average shares are shown by province

Table A2 Attritions – Linear probability

Dependent: = 1 if attrition in 2007-2010 and 0 otherwise	Height z-score		Weight z-score	
Sample: Age 0-6 in 2007				
Price change (index/village): Laspeyres index				
Weights for price index:	Quantity	Calorie	Quantity	Calorie
Non-producer	-0.0589	0.0154	0.0206	0.0503
	(0.46)	(0.12)	(0.35)	(0.90)
Price change (index/village)	0.0004	0.0005	0.0005	0.0005
	(0.81)	(1.14)	(1.67)	(1.69)
Price change (index/village) * Non-producer	0.0002	-0.0001	-0.0001	-0.0002
	(0.42)	(0.19)	(0.32)	(0.93)
Age 2007 (months)	-0.0002	-0.0002	0.0016	0.0016
	(0.09)	(0.09)	(1.31)	(1.40)
Age 2007 squared	-7.55E-06	-7.12E-06	-2.00E-05	-2.00E-05
	(0.32)	(0.29)	(1.43)	(1.52)
Male	0.0077	0.0069	0.0093	0.0089
	(0.32)	(0.29)	(0.78)	(0.75)
Log of birthweight (kg)	0.0039	0.0048	0.0306	0.0290
	(0.07)	(0.09)	(0.84)	(0.80)
Household size 2007	0.0029	0.0034	0.0013	0.0018
	(0.51)	(0.63)	(0.26)	(0.37)
Head male 2007	-0.0452	-0.0451	-0.0170	-0.0167
	(0.67)	(0.69)	(0.33)	(0.34)
Head age 2007	-0.0003	-0.0003	0.0006	0.0005
	(0.30)	(0.34)	(0.80)	(0.66)
Household income 2007	-1.12E-11	-1.01E-11	1.05E-11	1.11E-11
	(0.13)	(0.11)	(0.17)	(0.17)
Household income 2007 * Male	-9.04E-12	-9.15E-12	-1.11E-11	-1.24E-11
	(0.10)	(0.09)	(0.18)	(0.18)
Total assets 2007	2.46E-10	2.34E-10	2.42E-10	2.35E-10
	(1.80)	(1.76)	(1.68)	(1.66)
Total assets 2007 * Male	-1.17E-10	-1.13E-10	-1.24E-10	-1.23E-10
	(1.10)	(1.13)	(1.37)	(1.41)
Income loss	7.55E-10	7.97E-10	1.90E-10	2.07E-10
	(0.46)	(0.51)	(0.25)	(0.29)
Income loss * Total assets 2007	-5.24E-18	-5.20E-18	-3.95E-18	-3.93E-18
	(1.80)	(1.71)	(1.47)	(1.44)
Asphalt road	-0.0216	-0.0292	-0.0377	-0.0434
	(1.21)	(1.26)	(3.41)	(2.83)
Distance to provincial capital	-0.0001	-0.0001	-0.0002	-0.0002
	(1.33)	(1.50)	(4.22)	(4.08)
Asphalt * Distance	0.0000	0.0000	0.0001	0.0001
	(0.54)	(0.42)	(1.27)	(1.07)
Province dummies	yes	yes	yes	yes
Number of observations	584	584	592	592
R squared	0.0273	0.0263	0.0478	0.0476

Note: Numbers in parentheses are absolute t values using robust standard errors with province clusters.

Table A3 Alternative price indices

Dependent: Change in height z score				
Sample: Age 0-6 in 2007				
Price change index				
Weights:	Paasche		Fischer	
	Quantity	Calorie	Quantity	Calorie
Non-producer	0.8714	-0.3344	2.9407	2.2528
	(0.53)	(0.21)	(2.55)	(1.76)
Price change (index/village)	0.0043	0.0053	0.0064	0.0060
	(0.43)	(0.46)	(1.28)	(0.78)
Price change (index/village) * Non-producer	-0.0062	0.0013	-0.0155	-0.0130
	(0.61)	(0.12)	(2.68)	(1.90)
All other explanatory variables being included:	yes	yes	yes	yes
Number of observations	551	551	551	551
R squared	0.1127	0.1129	0.1192	0.1166

Note: Numbers in parentheses are absolute t values using robust standard errors with province clusters. All other explanatory variables used in Columns 3 and 4 in Table 3 are included