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The Impact of Early Childhood Nutritional Status on Cognitive Development: Does the Timing of Malnutrition Matter?

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This article uses longitudinal data from the Philippines to examine whether the timing of malnutrition in early childhood is a critical factor in determining subsequent cognitive development. Although some observers have argued that the first six months of life are the most critical in the sense that malnutrition during that time period harms cognitive development more than malnutrition later in life, analysis of the Philippines data does not support this claim. To the contrary, the data suggest that malnutrition in the second year of life may have a larger negative impact than malnutrition in the first year of life.

As developing countries have been making greater efforts to improve educational outcomes, policymakers are paying more attention to the role that child nutrition may play in both improving school readiness and increasing learning (see Young 1997 for a review). In many developing countries one third or even one half of all children are seriously stunted—height for age is two standard deviations or more below the World Health Organization reference median—before they enroll in primary school (UNICEF 1996). If poor nutrition does indeed impair educational performance, these high rates of malnutrition in the first years of life imply that a large proportion of children in these countries begin school with a serious learning handicap.

A growing literature documents the sizable correlation between childhood nutrition and school performance; however, evidence on the causal nature of this association is sparse, variable in quality, and often inconclusive. A few recent studies have examined the causal links by explicitly addressing underlying behavioral assumptions (see Alderman and others 1997, Behrman and Lavy 1994, and Glewwe and Jacoby 1995), yet none focus on a key aspect of the relation-

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ship between nutrition and school performance: does the timing of malnutrition during the first years of life matter?

Nutritionists and physiologists began to examine the issue of timing in the 1970s. Some argue that the time from early gestation to the first six months of life is the most critical for brain development, implying that inadequate nutrition during this period would have much more severe effects on children's cognitive development than would subsequent episodes of malnutrition. Recent research has raised doubts about these claims. Nonetheless, the question itself is of considerable policy interest because the existence of a critical period implies that nutritional interventions are most effective when administered during that period. In this article we use a longitudinal data set, the Cebu Longitudinal Health and Nutrition Survey (CLHNS), to examine the question of timing.

I. Early Childhood Nutrition and School Performance: A Brief Review of the Literature

Studies that link child nutrition and school performance typically show that malnutrition is correlated with poor school performance. But most of these studies do not test for causality, that is, whether poor nutrition causes poor school performance (see Grantham-McGregor 1995, Behrman 1996). Because disadvantaged children are more likely to be both undernourished and weak students, it is not clear whether their poor performance in school is primarily due to poor nutrition or to other aspects of their disadvantaged circumstances.

A few experimental and quasi-experimental studies generally support the hypothesis that causality runs from poor nutrition to poor school performance (Gorman 1995, Pollitt et al. 1995). Yet little is known about the mechanisms and processes that govern this causality, which hampers efforts to design more effective nutrition policies. The most likely pathways involve the effects of inadequate intake of calories, protein, and specific micronutrients on cognitive development, which in turn affect school readiness and performance.

A crucial unanswered question regarding the impact of childhood nutrition on educational outcomes is the relationship between the timing of early childhood malnutrition and subsequent school performance. Some nutritionists and child physiologists claim that there is a "critical period" during which brain development is most sensitive to poor nutrition. For example, Dobbing (1976) argued that the period from birth (or even from the last trimester of pregnancy) to six months of age is the most critical. This conjecture is based on the finding that the rate of brain growth (in terms of overall mass) in humans is highest during that period. Dobbing claimed that nutritional deficiencies ("insults") during this period have the greatest adverse impact on future cognitive development, whereas insults before or after this period do not result in permanent damage. However, correlation studies have not provided consistent evidence on this issue (Grantham-McGregor 1995), and some recent assessments by nutritionists (such as Levitsky and Strupp 1995) are increasingly skeptical of this hypothesis.

It is not easy to study how the timing of nutritional deficiencies affects cognitive development. In most developing countries, malnourished children typically receive both inadequate maternal nutrition and poor feeding throughout their infancy and early childhood. This correlation of nutritional insults over time complicates efforts to isolate the effects of poor nutrition during particular periods of a child's growth. In principle, supplementation studies, particularly those in which some children are randomly given nutritional supplements and others are not, can shed light on this issue. Yet most experimental studies focus on the effectiveness of interventions at a particular period of the child's life and do not randomize supplementation across time periods.

The only published experimental study that explicitly examines the issue of timing is that of Waber and others (1981). In that study 433 children were randomly assigned to one control group and five different treatment groups. In three of the treatment groups the nutritional supplements were administered in different time periods. One group of children received nutritional supplements from the third trimester of their mother's pregnancy until 6 months of age (prenatal supplements were given to the child's mother), a second group received supplements from 6 months to 36 months, and the third received supplements from the third trimester to 36 months. The results did not support Dobbing's hypothesis. Children who received supplements from 6 months to 36 months and from the third trimester to 36 months performed better on tests of mental development than did the control group. But children who received the supplements only from the third trimester to six months did not. Furthermore, the authors found no difference between children who received supplements from the third trimester to 36 months and children who received them from 6 to 36 months. These findings suggest that if there is any critical period, it may be after six months of age. Further research is needed before major policy decisions can be made.

Two other studies relevant to the issue of timing are Stein and colleagues (1975) and Villar and colleagues (1984). Stein and his colleagues examined the impact of wartime famine in the Netherlands in 1944–45 on children who were born immediately after the famine. Their intent is to determine whether prenatal malnutrition has a substantial impact on subsequent mental development. When these children reached adulthood, their IQ scores revealed no evidence that exposure to famine during their mothers' pregnancy had any effect on their cognitive development later in life.

Villar and his coauthors, however, found evidence that prenatal nutrition is an important determinant of subsequent cognitive performance. They also focused on prenatal nutrition, using data on 205 Guatemalan infants. They distinguished between two groups of full-term infants with low birth weights and compared each to a control group of children with normal birth weights. At birth, the two low-birth-weight groups had similar weights but differed in length and head circumference. The low-birth-weight babies who had longer lengths (and thus lower weight-to-length ratios) tended to catch up to the normal group soon after birth. The babies who were shorter in length remained lighter and shorter and had smaller head circumferences relative to the other low-birth-weight group, at least up to 30 months of age. Controlling for nutritional intake, morbidity, and environmental factors, the study also finds that infants whose head growth slowed before 26 weeks of gestation (as measured by ultrasound) scored lower in mental performance during preschool years and in behavior and school achievement during primary school years. Infants whose head growth slowed after 26 weeks of gestation did not differ from the normal birth-weight group, except for scoring lower on the McCarthy scale at five years of age.

In summary, there is little evidence on the impact of the timing of early childhood malnutrition on subsequent school performance, and the little that does exist gives mixed results, at least for prenatal nutrition. The next section provides a methodology for examining this issue using longitudinal household survey data.

II. THEORETICAL FRAMEWORK

In this section we present a simple model of nutrition and education outcomes that highlights the relationship between early childhood nutrition and subsequent school performance. We develop the model to ensure that appropriate econometric methods are employed. Anticipating the information available in our data, we focus on the impact of early childhood nutrition on children's "ability to learn," commonly referred to as IQ. The fundamental determinants of IQ at time t are:

$$IQ_t = f(NUTR_0, NUTR_1, \ldots NUTR_t; EXTST_0, EXTST_1, \ldots EXTST_t; \sigma). \tag{1}$$

Equation 1 states that a child's IQ at time t is determined by his or her nutrition history (denoted by $NUTR$ with time subscripts from 0 to t), a similar history of external sensory stimulation provided by the child's family, school, and other environmental factors (denoted by $EXTST$, with time subscripts), and the child's genetic endowment of "innate intelligence" (σ).

Equation 1 is a structural relationship, that of a "production function" for IQ. It is difficult, if not impossible, to estimate. One problem is that children's nutritional status and external stimulation at each point in time are not exogenous. A second problem is that external stimulation and innate intelligence cannot be observed. One way to get around the inability to observe external stimulation is to substitute it out of equation 1. To do so, assume that external stimulation is determined by several factors, such as parental education ($PARNTED$), initial household wealth ($WLTH_0$), parents' tastes for educating their children (θ), children's innate ability (σ), and the educational characteristics—such as school quality and availability and cultural norms—of the local environment ($EDENV$) at each point in time. Children's current nutritional status should also be included, because it can affect external stimulation; for example, children who are ill may spend more time resting in bed and, when older, may miss more days of school. Moreover, past nutritional status may matter because parents may adjust current external stimulation in response to past nutritional outcomes.

These determinants of external stimulation can be expressed as

$$EXTST_t = g_t(PARNTED,\ WLTH_0,\ \theta,\ \sigma;\ NUTR_0,\ NUTR_1,\ \ldots\ NUTR_t;\ EDENV_0,\ EDENV_1,\ \ldots\ EDENV_t;\ \varepsilon_0,\ \varepsilon_1 \ldots \varepsilon_t). \quad (2)$$

For completeness, equation 2 includes random factors beyond parents' control (denoted by ε) that may affect external stimulation at each point in time. In equation 2 children's nutritional status at each point in time is endogenous, but all other variables (including the random factors) are beyond parents' control.[1] Substituting equation 2 into equation 1 yields the following equation:

$$IQ_t = f(NUTR_0,\ \ldots\ NUTR_t;\ PARNTED,\ WLTH_0,\ \theta,\ \sigma;\ EDENV_0,\ \ldots\ EDENV_t;\ \varepsilon_0,\ \varepsilon_1 \ldots \varepsilon_t) \quad (3)$$

For empirical work equation 3 is more useful than equation 1—most types of external stimulation are not observed, whereas most (but not all) determinants of external stimulation can be observed.

III. ECONOMETRIC IMPLICATIONS

We can follow two possible routes in attempting to assess the impact of the timing of malnutrition on cognitive development. The first is to estimate equation 3 directly. Such estimates, if accurate, would provide direct evidence of the impact of children's nutrition on cognitive development at different time periods. Unfortunately, there are serious obstacles to obtaining unbiased estimates, as explained below. The alternative route is to substitute out the nutritional status (NUTR) variables in equation 3 and replace them with the exogenous variables that determine nutritional status. If some of the exogenous variables vary over the different time periods, one may be able to draw inferences about the impact of the timing of malnutrition on cognitive development from these reduced-form estimates. However, difficulties can arise when drawing such inferences. We present both types of estimates in section V.

Instrumental Variable Estimation

Consider estimating equation 3. It is not a production function for IQ for two reasons. First, the external stimulation variables in equation 1 have been substituted out. Second, the impact of $NUTR_t$ on IQ in equation 3 reflects both the direct biological mechanisms of equation 1 and the indirect mechanisms that reflect human behavior through the impact of nutritional status on external stimulation (as shown in equation 2).[2] Thus, equation 3 is a conditional demand func-

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[1] Community characteristics may be within parents' control if they migrate or organize to demand government services. This issue is set aside for now, but is dealt with during estimation.

[2] One might try to eliminate this indirect effect by specifying equation 2 as the reduced-form determinants of external stimulation, that is, by replacing $NUTR_t$ in equation 2 with the exogenous factors that determine it. Yet doing so eliminates all candidates for instrumental variables in equation 3, because all determinants of NUTR belong in equation 2 and thus are already in equation 3.

tion, the "demand" for IQ conditional on the child's nutritional status and a set of exogenous variables. Although our inability to estimate the production function in equation 1 may be disappointing, from a policy perspective conditional demand estimates are useful because they are sufficient for understanding the overall impact of nutritional status on subsequent cognitive development.

We turn now to the nutritional status variables ($NUTR$) in equation 3, which are still endogenous. They are structurally determined by a production function, the inputs being nutrient intakes (calories, protein, micronutrients), exposure to infectious diseases, and medical treatments received. An important point to keep in mind is that among the exogenous variables that determine children's nutritional status may be parental tastes for children's nutrition and the availability of local medical services, both of which should improve children's nutritional status.

Ideally, one would like data on nutritional status. Unfortunately, such basic medical data—that is, data on metabolic processes taking place within the human body—are rarely available, and our Philippines data are no exception. However, among infants and young children the outward manifestation of good nutritional status is physical growth. In general, increases in height are probably the best single indicator of a child's nutritional status, although this relationship contains some random measurement error. Thus, we use changes in height to measure children's nutritional status for each time period t:

$$DHEIGHT_t = NUTR_t + \mu_t \tag{4}$$

where μ_t is random measurement error. Similarly, a general indicator of prenatal nutrition is birth weight, although, again, measurement error will arise:

$$BW = NUTR_0 + \mu_0. \tag{5}$$

A key assumption in equations 4 and 5 is that the error terms (μ_t and μ_0) reflect only measurement error. But they may also reflect other factors. In particular, although net intakes of calories and protein (that is, effective intakes after accounting for wastage due to diarrhea and other health problems) are highly correlated with growth, other nutritional deficiencies, such as micronutrient deficiencies, do not necessarily reduce growth. The μ's in equations 4 and 5 may thus include aspects of a child's nutritional status that are not reflected in growth. As explained below, this could lead to biased parameter estimates.

Using equations 4 and 5 to substitute for nutritional status in equation 3, and assuming a simple linear form, yields

$$\begin{aligned} IQ_t = {} & \beta_0 + \beta_1 BW + \Sigma_t \beta_{2t} DHEIGHT_t + \beta_3 PARNTED + \beta_4 WLTH_0 + \beta_5 \theta \\ & + \Sigma_t \beta_{6t} EDENV_t + \beta_7 \sigma + e_t \end{aligned} \tag{6}$$

where the residual term e is generated by the random factors (ε's) that determine external stimulation, the μs in equations 4 and 5, and any measurement error in the IQ test itself.

Ordinary least squares (OLS) estimates of the parameters in equation 6 are likely to be biased for three reasons. First, some aspects of the local educational environment may not be observed, so that a portion of the EDENV variable is captured by the error term. This will lead to overestimation of β_6 in equation 6. Moreover, these unobserved components may be correlated with the availability and quality of local health services and thus correlated with birth weight and increases in height. This would lead to overestimation of β_1 and the β_2's in equation 6. We avoid these problems here by using a community fixed-effects procedure to estimate equation 6.

Second, a child's nutritional status, as measured by birth weight and changes in height, may be correlated with unobserved parental tastes regarding their child's nutrition. If such tastes are correlated with tastes for educating children (for example, both are manifestations of preferences for child "quality"), θ will be positively correlated with both birth weight and change in height, biasing upward OLS estimates of β_1 and the various β_2's. Thus, suitable instruments must be found for birth weight and the change in height. These variables also must be instrumented because they measure nutritional status with error, thus biasing estimates of both coefficients toward zero.

Third, birth weight and changes in height may not fully reflect children's nutritional status. As explained above, this means that μ_0 and μ_t in equations 4 and 5 could reflect not only measurement error but also aspects of nutritional status that have little effect on growth. If so, some components of the NUTR variables will be relegated to the error term, e_t, which includes the μ's. Thus, even when we can find good instruments for birth weight and changes in height, these instruments may be correlated with e_t in equation 6, leading to biased estimates. The direction of bias depends on whether the nutritional problems not reflected in physical growth are more or less severe than those that are reflected in growth.[3]

Because the second and third problems are closely tied to instrumental variable methods, we consider the choice of instruments for birth weight and child growth. To deal with the second problem, the instruments must be correlated with one or both of these variables but uncorrelated with parental tastes (θ) or a child's inherited ability to learn (σ), both of which are unobserved variables in equation 6. Two sets of variables that would appear to satisfy these criteria are local prices and fluctuations in the physical environment. Unfortunately, the use of community fixed effects to resolve the first problem rules out a large number of potential instruments; the remaining ones are those that vary over relatively short periods of time *within* each community. Variation in prices of major food items (such as corn) leads to variation in real income and the relative price of food, both of which are important determinants of health status.

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[3] To see this, suppose $DHEIGHT_t = NUTR_t + \mu_t + \nu_t$, where ν_t accounts for a nutritional deficiency that does not reduce growth appreciably. If this deficiency were severe, whereas deficiencies that affect growth were relatively mild, ν_t would be positive (growth overestimates aggregate nutritional status). Instruments that are positively correlated with nutritional status would then be negatively correlated with ν_t, which would be part of the error term e_t. In contrast, if deficiencies that strongly affect growth were relatively severe, the correlation between the instruments and ν_t would be positive.

Variation in rainfall can also serve as an instrumental variable, because heavy rainfall may disrupt income-earning activities or raise individuals' exposure to disease-spreading pathogens. Fortunately, the CLHNS data include both price and rainfall variables.

Other potential instrumental variables are mothers' characteristics.[4] One is maternal height, which should reflect both normal variation in height among a healthy population and variation in the genetic health endowment of mothers and their children. Also useful are indicators of mothers' health during pregnancy. Poor maternal health could reduce birth weight and slow weight gain while the child is nursing, but should have no direct effect thereafter.

This group of instrumental variables appears to resolve the second econometric problem. It is difficult to imagine how the price and rainfall variables could be correlated with parental tastes (θ) or a child's ability to learn (σ), and thus they should be uncorrelated with the error term in the second-stage regression. The two variables indicating mothers' health status also seem reasonable, although one could think of reasons why they could be correlated with children's cognitive development (for example, a mother's poor health during pregnancy could be correlated with her health later in life, which in turn could directly affect her child's cognitive development). Even so, almost any instrumental variable that predicts *NUTR* might have at least a small effect on IQ. Because *NUTR* and IQ are endogenous, any general behavioral model will show that virtually all exogenous variables are determinants of both. Even food prices during infancy can be criticized—they might affect purchases of educational toys for children, which would in turn directly affect IQ.

The third problem can also raise doubts about the validity of these instrumental variables. The problem is that birth weight and changes in height may not fully measure children's nutritional status. For example, they may not reflect micronutrient deficiencies, implying that e_t in equation 6 could be correlated with the instruments. Yet these potential biases could go in any direction and may be small. First, although micronutrient deficiencies are conceptually different from inadequate intakes of calories and protein (which are well measured by a child's growth), they tend to be highly correlated with calorie and protein deficiencies. This occurs because low-income households not only have lower calorie and protein intakes but also have less diverse diets (more staples and less meat and vegetables), which leads to micronutrient deficiencies. Because of the correlation between calorie and protein intakes and micronutrient intakes, child growth may reflect micronutrient deficiencies, leaving little scope for such deficiencies to be reflected in the error term in equation 6. Second, even if bias occurs, it is likely to have similar effects on the coefficients for birth weight and change in height; such biases will have little effect on comparisons of the *relative* magnitudes of these coefficients.

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[4] We could also use father's characteristics. Regrettably, the CLHNS data contain less information on fathers than on mothers. For example, no anthropometric data were collected from fathers.

Reduced-Form Model

Given these considerations, can we estimate equation 6 with the instrumental variables proposed here? Some researchers may consider the problems discussed above to be minor and thus unlikely to lead to serious biases; others would disagree. This dilemma arises in virtually any conventional application of instrumental variable methods. In this article we take a two-pronged approach. First, we present instrumental variable estimates, noting the potential for bias. In addition, we check the validity of the instruments using standard overidentification tests (see Davidson and MacKinnon 1993). Although the power of these tests to reject a false null hypothesis may be small, our relatively large sample size should increase that power. Second, we also present reduced-form estimates and attempt to draw inferences from these results.

We can obtain reduced-form estimates of the determinants of children's IQ scores by substituting out the nutritional status variables (*NUTR*) in equation 3. In particular, at any point in time the most important exogenous variables that determine nutritional status are past and current food prices (*FOODPR*), the mother's health during pregnancy (*MOMPRHLTH*), the child's health endowment (ω), parental tastes for child health (ϕ), parental education, initial wealth, and past and current aspects of the local health environment (*HLTHENV*):

$$(7) \qquad NUTR_t = h(FOODPR_0, \ldots FOODPR_t; MOMPRHLTH, \omega, \phi, PARNTED, WLTH_0; HLTHENV_0, \ldots HLTHENV_t; \eta_0, \eta_1, \ldots \eta_t).$$

As in equation 2, equation 7 includes random exogenous factors that may affect a child's health, denoted by the η's.

The reduced-form equation of the determinants of children's cognitive development is obtained by substituting equation 7 into equation 3:

$$(8) \qquad IQ_t = f(FOODPR_0, \ldots FOODPR_t; MOMPRHLTH, \omega, \phi, PARNTED, WLTH_0, \theta, \sigma; EDENV_0, \ldots EDENV_t; HLTHENV_0 \ldots HLTHENV_t; u_0, u_1 \ldots u_t).$$

In equation 8 the *u*'s are aggregates of the η's and the ε's. To estimate this equation, we classify the health environment variables as two types: those that change slowly over time, such as the availability of health clinics, and those that change rapidly, such as weather conditions. The health variables that change slowly, along with the educational environment (*EDENV*) variables, can be replaced in equation 8 by community fixed effects.

What can we infer about the impact of the timing of malnutrition on subsequent cognitive development from equation 8? Consider food prices and the health environment variables that can vary substantially over short time periods. If nutrition during, say, the first six months of life plays a crucial role in cognitive development, then the food prices (and weather variables) prevailing during those six months should have statistically significant effects. Simple

F-tests of the joint significance of variables grouped by time periods can determine this. Yet this approach could be inconclusive for several reasons. First, the structural determinants of cognitive development at time period t may include cognitive development at time $t - 1$, and the same is true of the structural determinants of nutritional status. This clouds the interpretation of the impact of prices (and weather variables) in the earlier time periods: Part of their effect on cognitive development at time t may work through nutritional status in earlier periods, whereas another part may manifest itself through nutritional status in more recent time periods.

Second, much of what determines nutritional status and cognitive development may not be observed and is thus relegated to the error term. This reduces the precision of all the estimated parameters. Third, the price and rainfall variables may contain substantial measurement error, causing the true parameters to be underestimated (recall that conditional demand estimates avoid this attenuation bias through the use of instrumental variables). Fourth, different food items may have significant effects on children at different ages, and comparing the relative magnitudes may be problematic. The extent of these problems is difficult to determine a priori and may be unclear even after examining estimates of equation 8. In any event, interpretations of the estimates must not overlook these potential problems.

To summarize, there are two ways to investigate whether the timing of malnutrition in early childhood is a critical factor for subsequent cognitive development. First, one can estimate reduced-form relationships of the determinants of cognitive development and attempt to draw inferences based on the impacts of exogenous variables associated with the different time periods. Although this method avoids problems associated with instrumental variable estimates, the results may not lend themselves to clear interpretations. Second, one can use instrumental variable methods that, if accurate, yield parameters that are easier to interpret. However, the problem here is that additional econometric assumptions are required, and violations of these assumptions may produce misleading results. We carry out both types of estimations.

IV. Data and Empirical Implementation

We use data from the CLHNS, a joint undertaking of the Office of Population Studies at the University of San Carlos, the Philippines, and the Carolina Population Center of the University of North Carolina. The CLHNS sampled 3,080 children born in 33 *barangays* (communities) in the metropolitan Cebu area between May 1, 1983, and April 30, 1984. The first interview was conducted when mothers were six to seven months pregnant. Detailed health and nutrition data were gathered on the child and the mother every two months during the first two years of the child's life. For full details, see Office of Population Studies (1989).

The initial plan for the CLHNS was to collect data only for the first two years of each child's life. But a follow-up survey was implemented in 1991, when the children were about eight years old. This survey collected data on both the mother and her child for the 2,264 children who could be located.[5] In addition, all children took the Philippines Nonverbal Intelligence Test. This test was developed specifically for the Philippines by a team of psychologists (see Guthrie, Tayag, and Jacobs 1977). We use the score on this test, which was administered to 2,256 of the 2,264 children, as the general indicator of cognitive development.

Before turning to the estimation results, several data issues require further discussion. First, we must decide how many time periods to include in estimates of equation 6. Should we aggregate the 12 interviews conducted during the first two years the children's lives? There are problems with both too much and too little aggregation. A large amount of aggregation implies a small number of relatively long time periods. A consequent problem is that critical periods may be overlooked because their effects are diluted by being averaged out over a longer period. Little or no aggregation implies many short time periods; the difficulty here is that many instrumental variables are needed, increasing the probability that the endogenous variables cannot be identified. In section IV we use two sets of time periods, two 12-month periods and four 6-month periods, to check the robustness of the results.

A second issue concerns the rainfall data, which we use as instrumental variables for equation 6 and enter directly as regressors in equation 8. The CLHNS data include two rainfall variables. The first is the rainfall in each barangay during the time period in question. These figures are not exact because they are based on records from only 11 weather stations, most of which were not located in the 33 barangays sampled in the CLHNS, and because some observations are missing. These rainfall estimates are based on the work of Vanderslice (1987). The other rainfall variable is the proportion of months in a given time period that are part of the rainy season (from June to November); children in the sample will vary in terms of the proportion of their first six months of life that take place in the rainy season. Two points are worth noting about this variable. First, there is no sense in creating a second variable, the fraction of rainy season months during the second six months of life, because it would be perfectly correlated with the original variable and thus be redundant. Second, a rainy season variable constructed for one year, rather than six months, will have no variation. Yet this does not imply that information about the rainy season months has no predictive power on nutritional status when early childhood is divided into one-year periods. For example, the rainy season variable defined over the first six months of life will still vary across children and may well have predictive power for children's growth during the first year of life.

Third, consider the price variables. As with the rainfall variables (but unlike the rainy season variable), the price variables can be defined in terms of specific

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[5] Of the 827 children (27 percent of the total sample) not located in 1991, 472 (15 percent) had migrated out of the metro Cebu area, 205 (7 percent) had died, 125 (4 percent) could not be traced, and 25 (1 percent) could not be interviewed because they refused or for other reasons.

intervals of each child's life, for example, the average price of corn during a child's first six months, during the second six months, and so on. The food items used are corn, bananas, infant formula, and Cerelac (a dry cereal powder that is prepared by mixing with water).

A fourth data issue is the choice of variables to use for mothers' health status. A good indicator of maternal health during the third trimester of pregnancy is middle upper arm circumference, which indicates both energy (fat) and protein (muscle) reserves.[6] This variable should be correlated with birth weight and early childhood growth (until weaning is completed). We use it and the mothers' heights to measure the mothers' health status.

A fifth issue concerns the use of instrumental variables to estimate equation 6. We must go beyond the necessary condition that the number of instruments equal or exceed the number of variables being instrumented. For example, all of the instruments may be good predictors of nutritional status in the first months of life, but none may have predictive power in later years. A second potential problem is that some of the instruments may be highly correlated with others. Fortunately, the instruments discussed above should cover all of the time periods. Those that reflect mother's health during pregnancy should have the most predictive power for birth weight and the first months of life (during which the infant is breastfeeding). Those relating to rainfall, as well as prices for infant formula and infant foods, are more relevant for the weaning period, which begins around 6 months and ends by 18 or 24 months. General price variation and inherited health (that is, mother's height) should be relevant for almost all time periods. In any case, the first-stage regressions must be carefully examined to verify that the instruments have adequate predictive power for each time period considered.

Finally, one should check the data to see whether estimation of equation 6 can identify the impact of malnutrition at each time period. A necessary condition is that episodes of malnutrition must not be highly correlated over time; more specifically, changes in height at different times should not be highly correlated with each other nor with birth weight. This condition is met by the data. Birth weight and changes in height are remarkably uncorrelated over time (table 1). A related concern is whether the proposed instrumental variables are highly correlated. Fortunately, the instrumental variables capturing the mothers' characteristics are not highly correlated; the correlation coefficient for mother's height and mid-arm circumference during pregnancy is only 0.205.

V. ESTIMATION RESULTS

In this section we present estimates of equations 6 and 8 using the CLHNS data. Before doing so, it is useful to present simple descriptive statistics of key variables (table 2). The dependent variable, the score on the Philippines Nonverbal Intelligence test, ranges from 12 to 91, with a mean of 51 and a standard deviation of

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[6] Mothers' subcutaneous skinfold thickness is also in the CLHNS data. In a preliminary analysis it displayed no explanatory power and thus is excluded from the estimates presented here.

Table 1. Correlation Coefficients of Child Nutrition Variables

				Growth		
	Birth weight	0–6 months	6–12 months	12–18 months	18–24 months	2–8 years
Birth weight	1.000					
Growth						
0–6 months	–0.102	1.000				
6–12 months	0.001	–0.188	1.000			
12–18 months	0.009	0.043	–0.128	1.000		
18–24 months	–0.037	0.009	0.029	–0.118	1.000	
2–8 years	0.029	0.085	0.024	0.012	–0.123	1.000

Source: Authors' calculations.

12. About half of the sampled children are girls. The mean (log) years of schooling is similar for both parents. At this point, there is nothing particularly remarkable about the price, rainfall, and mothers' health variables that are used as instruments in equation 6 and entered directly into equation 8, but we use this information below. For brevity, we show only the price and rainfall variables for the first six months of a child's life; for the other time periods the means are similar.

Table 2. Descriptive Statistics from Cebu Longitudinal Health and Nutrition Survey

Variable	Mean	Standard deviation
IQ score	51.40	12.50
Sex (female = 1)	0.47	0.50
Log mother's schooling (years)	1.86	0.59
Log father's schooling (years)	1.88	0.62
Log value of household assets (when mother was pregnant)	7.79	1.66
Mother's height (cm.)	150.61	4.99
Mother's arm circumference during pregnancy (cm.)	24.65	2.34
Percentage of rainy season in first 6 months	0.53	0.29
Rainfall days 0–6 months (cm.)	73.91	28.89
Price of banana during 0–6 months	20.04	4.31
Price of corn during 0–6 months	232.52	27.84
Price of formula during 0–6 months	369.62	51.50
Price of Cerelac during 0–6 months	321.44	22.23
Birth weight (kg.)	3.00	0.42
Growth 0–6 months (cm.)	15.05	2.34
Growth 6–12 months (cm.)	6.42	1.85
Growth 12–18 months (cm.)	4.41	1.64
Growth 18–24 months (cm.)	4.01	1.61
Growth 2–8 years (cm.)	38.40	4.02

Note: Prices are per kilogram, except the price of formula, which is per container.

Source: Authors' calculations.

More interesting are the child growth variables. The mean birth weight of 3.0 kg is typical for a healthy population of children. Mean growth during the first six months of life is high, but in later months it slows considerably, another typical result. What is not evident from table 2 is that by age two, 64 percent of children have height-for-age *Z*-scores less than –2.0, indicating pervasive stunting. Only 2–3 percent of well-nourished children would be in this category.

Reduced-Form Estimates

In this subsection we present estimates of equation 8, the reduced-form determinants of children's cognitive development at age eight as measured by the Philippines Nonverbal Intelligence Test. We present these estimates first because they require fewer econometric assumptions than do the conditional demand estimates, which we present later. We estimate three versions of equation 8 (table 3).[7] The first equation does not include mother's height nor mother's arm circumference, the second includes only mother's height, and the third includes both. We treat these variables cautiously because they may be correlated with the error term. However, neither has a significant effect on IQ scores, so most of the discussion is confined to the first set of estimates.

The first four explanatory variables in table 3 have a positive and statistically significant impact on IQ scores, as expected. Girls score slightly better than boys, which is typical for the Philippines (see Tan, Lane, and Lassibille 1997). Also typical are the findings that the schooling of both mothers and fathers has a strong impact and that children from wealthier households have higher cognitive development.

The fraction of the first six months of the child's life that fall in the rainy season has a significantly negative impact, which may lead to the conjecture that the associated nutritional insults during that time period have a significant negative impact on children's cognitive development. But because this variable is perfectly correlated with the fraction of rainy season months in the second six months of the child's life, the third six months, and so on, we cannot infer anything from this result regarding the timing of malnutrition.

We disaggregate each of the remaining variables in the first set of estimates in table 3 into the four six-month time periods corresponding to the first two years of life. Unfortunately, similar data were not available for any time period after two years of age. That omission may not be serious, however, because nutritional data consistently show that almost all shortfalls in height occur during the first two years.[8] Two of these variables, rainfall and banana prices, never have a significant impact on children's IQ scores. As mentioned in section IV, the rainfall variable is measured with error; these errors are probably random

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[7] All estimates use community fixed effects. The communities are not those in which the mothers and children now live, but those in which the children were born. This should minimize bias arising from selective migration, which could make community variables endogenous.

[8] The conditional demand estimates presented in the next subsection examine nutritional status between two and eight years of age.

Table 3. Reduced Form Estimates of the Determinants of IQ Scores

Variable	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
Sex (female)	1.007*	0.518	1.023**	0.518	1.021**	0.518
Log mother's schooling	3.744***	0.564	3.702***	0.565	3.704***	0.566
Log father's schooling	4.157***	0.537	4.105***	0.539	4.095***	0.540
Log value household assets	0.720***	0.174	0.705***	0.175	0.697***	0.176
Percentage rainy months in first 6 months	−7.125***	1.959	−7.011***	1.963	−7.006***	1.963
Rainfall 0–6 months	−0.020	0.013	−0.020	0.013	−0.020	0.013
Rainfall 6–12 months	0.012	0.013	0.012	0.013	0.012	0.013
Rainfall 12–18 months	0.002	0.010	0.002	0.010	0.002	0.010
Rainfall 18–24 months	−0.003	0.010	−0.003	0.010	−0.003	0.010
Price bananas 0–6 months	0.028	0.096	0.028	0.096	0.027	0.096
Price bananas 6–12 months	0.067	0.153	0.063	0.153	0.062	0.153
Price bananas 12–18 months	0.127	0.128	0.123	0.128	0.123	0.128
Price bananas 18–24 months	0.019	0.129	0.019	0.129	0.019	0.129
Price corn 0–6 months	0.017	0.023	0.018	0.023	0.018	0.023
Price corn 6–12 months	−0.023	0.023	−0.022	0.023	−0.023	0.023
Price corn 12–18 months	−0.032	0.023	−0.032	0.023	−0.032	0.023
Price corn 18–24 months	−0.054***	0.020	−0.054***	0.020	−0.054***	0.021
Price formula 0–6 months	0.000	0.010	0.000	0.010	0.000	0.010
Price formula 6–12 months	−0.024*	0.014	−0.025*	0.014	−0.025*	0.014
Price formula 12–18 months	−0.015	0.015	−0.016	0.015	−0.016	0.015
Price formula 18–24 months	0.006	0.015	0.006	0.015	0.006	0.015
Price Cerelac 0–6 months	−0.008	0.027	−0.007	0.027	−0.007	0.027
Price Cerelac 6–12 months	0.011	0.024	0.011	0.024	0.011	0.024
Price Cerelac 12–18 months	0.015	0.021	0.014	0.021	0.014	0.021
Price Cerelac 18–24 months	0.045**	0.018	0.045**	0.018	0.045**	0.018
Mother's height			0.052	0.054	0.048	0.055
Mother's arm circumference					0.047	0.114
R^2	0.238		0.238		0.238	
Sample size	1,911		1,911		1,911	

Notes:
*Significant at the 10 percent level.
**Significant at the 5 percent level.
***Significant at the 1 percent level.
Source: Authors' calculations.

and thus would bias parameter estimates toward zero. As for banana prices, although bananas are consumed widely in the Philippines, they are not a staple, so changes in their price probably have only a small effect on food intake.

The prices of corn, infant formula, and Cerelac do have statistically significant impacts on IQ scores, at least in some time periods. When a child is 18–24 months old, corn prices have a negative impact that is significant at the 1 percent level, at 6–12 months infant formula prices have a negative impact that is significant at the 10 percent level, and at 18–24 months Cerelac prices have a positive impact that is significant at the 5 percent level. The sign of the coefficients on corn and infant formula and the timing of effects make sense. Infant formula is most important during a child's first 12 months of life, whereas consumption of corn is probably not significant until 6 or 12 months of age. The timing of the Cerelac effect is plausible, but not the positive sign. Overall, the results in table 3 suggest that price changes at 18–24 months, and perhaps also at 6–12 months, could lead to nutritional insults that affect children's cognitive development. It is also possible that nutritional insults at 0–6 months and 12–18 months affect cognitive development, if the flooding picked up in the rainy season variable reflects events at these ages.

A more formal way to check for the impact of timing is to test for the joint significance of the price and rainfall variables when grouped by different time periods (table 4). Joint tests of the rainfall variable and the four food price variables show no statistical significance during the first three six-month periods, but for the fourth period (18–24 months) they are significant at the 10 percent level. If the rainfall variable is dropped the results are similar except that the *F*-test for 18–24 months is almost significant at the 5 percent level (*p*-value of 0.051). These results are consistent with those of table 3.

Another check of the regressions in table 3 pertains to correlation between the four price variables. In some cases the correlation is high, which is plausible because food prices may move together over both space and time. Of particular interest is the high correlation coefficient (0.73) of corn and Cerelac prices during the 18–24 month period, which may explain why they are both significant but have opposite signs. Although *F*-tests should eliminate spurious significant results caused by such high correlation, we can check for such results by reesti-

TABLE 4. Statistical Significance of Time-Varying Variables

	0–6 Months	6–12 Months	12–18 Months	18–24 Months
Rainfall, bananas, corn, formula, Cerelac	0.53	0.99	0.86	1.89
F (5,1853)	[0.751]	[0.422]	[0.504]	[0.092]
Bananas, corn, formula, Cerelac	0.17	1.10	1.06	2.36
F (4,1853)	[0.954]	[0.355]	[0.374]	[0.051]

Source: Authors' calculations.

mating the first regression in table 3 twice, once omitting Cerelac prices and once omitting corn prices. In the first regression (not shown here) the parameter for the price of corn is still negative but is reduced by nearly half (from –0.054 to –0.028) and is significant only at the 10 percent level. In the second regression the coefficient on the price of Cerelac remains positive but is reduced by two-thirds (from 0.045 to 0.017) and is insignificant (*t*-value of 1.10). Thus the strong statistical significance for these two variables for the period 18–24 months may have been exaggerated, although the price of corn is still significant at the 10 percent level.

Do these reduced-form estimates tell us anything about the impact of the timing of malnutrition on children's cognitive development? Although caution is needed, we can draw some tentative inferences. First, the insignificant impacts on IQ scores of both mother's height and mother's arm circumference suggests that prenatal nutrition may not be very important. In particular, these variables are strong predictors of birth weight (as we will see in the next subsection; see also table A-3 in the appendix), and if birth weight were strongly related to subsequent cognitive development these variables should be statistically significant predictors of IQ scores.

Second, there is no evidence that the crucial time period is the first six months of life and thus no support for Dobbing's thesis. Even so, some caution is needed because the strongly significant impact of the rainy season variable on children's IQ scores could reflect its impact during the first six months of life. Third, there is some evidence that malnutrition during the 18–24 month period matters, as picked up in the significant impact of corn prices (and perhaps Cerelac prices, although the unexpected sign and the disappearance of any significant effect after corn prices are dropped raises serious doubts) and the joint significance of all variables during that period. Fourth, there may also be an effect during the 6–12 month period, as seen by the weak significance of the infant formula variable for these months. However, the insignificant *F*-tests for that time period shows the weakness of this result.

A final exercise that may be useful for policymakers is to use the estimates in table 3 to assess the impacts on IQ scores of specific food price subsidies. Suppose that corn were subsidized to reduce its price by half, from 2.32 to 1.16 pesos per kg. The coefficient in table 3 suggests that IQ scores would increase by 6.3 points, about one half of its standard deviation. This is a sizable increase, yet the estimated coefficient is reduced by nearly half when Cerelac prices are omitted from the regression. Moreover, a subsidy on such a common staple would be extremely expensive. In contrast, subsidizing infant formula may be much less expensive, because it is consumed only by infants. Using the (admittedly imprecisely) estimated coefficient on infant formula prices during the first 6–12 months of life, a subsidy that reduces this price by half (from 3.70 to 1.85 pesos per can) would increase children's IQ scores by about 4.4 points. Although this impact is also imprecisely estimated, it is sizable. We must also consider that there other policies, such as interventions that provide child health or education services directly, that are much more economical ways to improve children's cognitive development. This will be examined below using the conditional demand estimates.

Conditional Demand Estimates

The reduced-form estimates reported above give only a little insight into the extent to which the timing of malnutrition affects children's cognitive development. Here, we present conditional demand estimates (estimates of equation 6). Although these estimates require additional econometric assumptions, conditional on those assumptions much more can be learned from the CLHNS data.

We estimate equation 6 using one-year intervals between birth and two years of age (table 5).[9] To investigate issues of timing, we divide early childhood into four time periods: prenatal, birth to one year, one to two years, and two to eight years. We cannot decompose prenatal growth into separate time periods (for example, the first, second, and third trimesters of pregnancy) with the CLHNS data, nor can we decompose the period from two to eight years. We take a relatively conservative approach in specifying the time periods from birth to two years, dividing this time period into two one-year periods, which minimizes the need for instrumental variables.

The estimated coefficients on parents' education, household assets, and sex in the OLS regression are not very different from their reduced-form counterparts in table 3 and thus need no further discussion (table 5). Each of the four indicators of childhood malnutrition has the expected positive sign, and three are highly significant (the exception, growth from two to eight years, is significant only at the 10 percent level). The relative magnitudes of the coefficients on birth weight and child growth can be compared in terms of the impact on IQ scores of a one standard deviation change in those variables (as seen in table 2). A one standard deviation increase in birth weight raises the IQ score by 1.0 points. The analogous figures for growth in the first and second years of life are 1.4 and 2.0, respectively.[10]

Finally, a one-standard-deviation increase in growth between two and eight years would raise IQ scores by 0.5 point. These impacts are small, given that the standard deviation of the IQ score is 12.5 points. If forced to compare the timing of interventions, and assuming no difference in the cost of increasing child growth by one standard deviation for each time period, an intervention during the second year is the most effective. Of course, for a rigorous comparison we would need the costs of various nutrition interventions and their impact on child growth in each time period, but this is beyond the scope of this article.

The OLS estimates in table 5 suggest that poor nutrition has significant effects on children's cognitive development in all time periods, at least up to two years

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[9] These estimates also use community fixed effects, according to where the children were born.

[10] The standard deviations of growth during the first and second years of life are 2.73 and 2.17, respectively.

Table 5. Fixed Effects Estimates of IQ Scores: One-Year Growth Intervals

		Two-stage least squares for different instrument sets		
Explanatory variables	OLS	Rainfall + price	Rainfall + price + mother's height	Rainfall + price + mother's height and arm circumference
Birth weight (kg)	2.297***	–1.396	–2.922	–0.544
	(0.634)	(7.052)	(6.172)	(3.914)
Growth 0–12 months (cm)	0.496***	0.161	0.001	–0.200
	(0.101)	(0.913)	(0.842)	(0.737)
Growth 12–24 months (cm)	0.937***	4.975***	4.848***	4.873***
	(0.132)	(0.966)	(0.926)	(0.924)
Growth 2–8 years (cm)	0.119*	–0.064	–0.172	–0.198
	(0.068)	(0.470)	(0.403)	(0.399)
Sex (female)	1.426***	0.879	0.786	0.714
	(0.543)	(1.431)	(1.421)	(1.412)
Log mother's schooling	2.974***	1.961**	2.084***	2.169***
	(0.571)	(0.845)	(0.801)	(0.781)
Log father's schooling	3.705***	2.233***	2.388***	2.410***
	(0.543)	(0.848)	(0.776)	(0.774)
Log value household assets	0.351**	–0.019	0.056	0.035
	(0.176)	(0.304)	(0.253)	(0.249)
R^2	0.236			
Observations	1,873	1,872	1,872	1,872
Chi-square tests				
Overidentification tests		21.22	21.15	21.62
Hausman test (d.f. = 4)		21.23***	22.08***	21.91***
F-tests for instruments				
Birth weight		1.25	3.74***	6.56***
Growth 0–12 months		2.07***	4.19***	4.03***
Growth 12–24 months		2.75***	3.35***	3.22***
Growth 2–8 years		3.12***	7.93***	7.95***

*Significant at the 10 percent level.

**Significant at the 5 percent level.

***Significant at the 1 percent level.

Notes: Standard errors are in parentheses. Parameter estimates for the 33 barangay dummy variables are not shown. Degrees of freedom for the overidentification tests are 17 in column 2, 18 in column 3, and 19 in column 4.

Source: Authors' calculations.

of age. The finding that prenatal nutrition matters is inconsistent with Stein and others (1975) and Waber and others (1981), but supports Villar and others (1984). Yet the OLS results may be misleading because tastes for child quality may induce correlation between child nutrition and cognitive performance that is not causally related. To address this problem, we use two-stage least squares (2SLS) for the remaining conditional demand estimates in table 5.

The first 2SLS estimate treats all four child nutrition variables as endogenous, using only price and rainfall variables as instruments (second column of table 5). The first-stage results are given in table A-1 in the appendix. These parameter estimates are different from the OLS results. Indeed, a Hausman test rejects the hypothesis that the two sets of estimates are equal. The most notable difference is that the coefficient on growth from one to two years increased fivefold relative to the OLS estimate. The 2SLS estimate implies that a one standard deviation increase in growth in the second year of life would increase a child's IQ by 10.1 points—a sizable increase. In contrast, the coefficients on the other three child nutrition variables decrease in absolute value and lose their statistical significance. These results are consistent with the Waber and Stein studies and suggest that the OLS estimates are biased.

The instrumental variables used for birth weight and changes in height have strong predictive power for three of the four child nutrition variables, as revealed by the *F*-test statistics (bottom of table 5). They easily pass standard overidentification tests, suggesting (but not proving) that they are not correlated with e_t in equation 6. Yet the price and rainfall instrumental variables are poor predictors of birth weight. Additional instrumental variables would also increase the precision of the other estimates. Thus we include instrumental variables based on mother's characteristics in the remaining estimates in table 5. The third column includes mothers' height while the fourth adds prenatal mid-upper arm circumference (the first-stage results are reported in appendix tables A-2 and A-3). In both cases the results are similar to those of the estimates that use only the price and rainfall variables as instruments: the only significantly positive coefficient is that on the second year of life. The *F*-tests also show greater precision (now the instruments have statistically significant predictive power for birth weight). Finally, Hausman tests again show significant differences from the OLS results, and the instruments pass overidentification tests.[11]

The 2SLS results in table 5 show that growth has a strong, positive, and statistically significant impact of growth on cognitive development during the second year of life. One might also conclude, based on the statistically insignificant effects for the other variables, that child nutrition matters *only* in the second year of life. Yet this inference is unwarranted because the standard errors of the birth weight and growth coefficients increase substantially when those child nutrition variables are instrumented. In particular, the 95 percent confidence intervals around the 2SLS estimates for birth weight, growth in the first year of life, and growth from two to eight years encompass the 95 percent confidence intervals of the respective OLS results, as seen in table 6. Thus one should not conclude that the true values for these variables are zero or even negative.

However, despite their larger standard errors, the 2SLS estimates do show an impact of poor nutrition during the second year of life on cognitive development

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[11] One anonymous referee suggested that the impact of child nutrition on IQ may be nonlinear. To test this we estimated the first and fourth columns of table 5 adding quadratic terms for the four nutrition variables. The OLS results were mixed, with two of the four variables (growth in the first year of life and growth between two and eight years) showing significant quadratic effects. However, all terms, both linear and quadratic, were insignificant in the 2SLS results. Apparently, the correlation between the linear and quadratic terms was too great for precise instrumental variable estimates, so we did not pursue this specification further.

Table 6. Point Estimates and Confidence Intervals for the Impact of Birthweight and Growth on IQ Scores

	OLS		2SLS	
	One unit increase (kg or cm)	Increase of one standard deviation	One unit increase (kg or cm)	Increase of one standard deviation
Birthweight (kg)	2.30	0.97	–0.54	–0.23
	(1.06–3.54)	(0.44–1.49)	(–8.21–7.13)	(–3.45–2.99)
Growth 0–12 months (cm)	0.50	1.37	–0.20	–0.55
	(0.30–0.70)	(0.82–1.91)	(–1.64–1.24)	(–4.48–3.39)
Growth 12–24 months (cm)	0.94	2.04	4.87	10.57
	(0.68–1.20)	(1.48–2.60)	(3.06–6.68)	(6.64–14.50)
Growth 2–8 years (cm)	0.12	0.48	–0.20	–0.80
	(–0.01–0.25)	(–0.04–1.01)	(–0.98–0.58)	(–3.94–2.33)

Notes: OLS and 2SLS estimates are from columns one and four of table 3, respectively. For each of the four nutrition variables, the first row is the point estimate and the second row is the 95 percent confidence interval.

Source: Authors' calculations.

that is stronger than the impact of poor nutrition in other time periods. We can compare these impacts in terms of one standard deviation changes in height or birth weight (as found in table 2 and note 10), because one centimeter of growth in the first year of life may not be equivalent to one centimeter of growth in later years, not to mention one-kilogram changes in birth weight (table 6).

Table 6 highlights two findings. First, the impact of a one-standard-deviation increase in growth during the second year of life is much higher in the 2SLS estimates than in the OLS estimates, a change not found for the other nutrition variables. That is, the confidence interval for the 2SLS estimates is from 6.6 to 14.5 IQ points, much higher than the OLS range of 1.5 to 2.6, and this upward shift does not occur for the other variables. Second, the 2SLS confidence intervals for each of the four nutrition variables show that a one-standard-deviation improvement in growth during the second year of life has a much larger impact on IQ than the one-standard-deviation changes of the other variables, even when comparing the upper endpoints of the confidence intervals for the latter (which range from 2.3 to 3.4) to the low endpoint of the confidence interval for growth in the second year (6.6).

The finding that a child's nutritional status during the second year of life may be more important than nutritional status during the first year clearly contradicts the claim that the most critical period is the first six months of life. That conjecture was based on biological evidence (specifically, during the first six months of life brain mass grows most quickly), so one may ask whether any biological research indicates a critical period later in life. Recent biological research shows that brain development is a complex process that spans a period of time much longer than the period of maximum brain growth, considered by Dobbing and others. Some critical developments (gliogenesis, macroneurogenesis, and early glial and neuronal migrations) precede the period of maximum brain growth and others (synaptogenesis and myelinization) occur after that period (Pollitt et al. 1996). If developments that occur after the period of maximum brain growth are more sensitive to malnutrition, the biological evidence is consistent with our findings. However, there is little precise evidence on the relative impact of malnutrition on the processes of brain development; the truth is that much is still unknown about the impact of poor nutrition on brain development.

Overall, the main findings of table 5 are that there is no support for the hypothesis that nutrition during the first year of life, or prenatal nutrition, is the most critical for cognitive development, and that there may be a critical period during the second year of life. Note that these findings are consistent with those of Waber and others (1981), the only experimental study designed to assess the relationship between mental development and the timing of malnutrition. Even so, these instrumental variable estimates could be biased, and so must be treated cautiously.

The good explanatory power of the instruments in table 5, and the fact that they easily pass the overidentification tests, suggests that we should divide the time period from birth to two years into smaller time periods. We divide those years into four six-month intervals (table 7). The general findings are the same. Although the OLS results indicate that all time periods have significant effects, the only significant effect in the 2SLS estimates is from 18 to 24 months. Dobbing's conjecture that the first six months are the most important again finds no support. Note that the standard errors in table 7 are very large for these six-month periods, sometimes nearly double the standard errors of the two one-year periods in table 5. This implies that division of the first two years of life into smaller time periods would probably produce even less precise estimates and thus yield no further useful information.

Because the findings in tables 5 and 7 are both strong and unexpected, we make two checks for robustness. First, we reestimate the regressions after dropping the 5 percent of observations with the largest residuals (in absolute value terms) in the original regression. Second, we randomly divide the sample into two equal subsamples. In each case the new estimates yield results that are similar to those shown in tables 5 and 7.

The reduced-form estimates can be used to examine the likely impact of an early childhood nutrition program. We have no data reporting the impact of such a program on child height from the Philippines, but a detailed study in India by Kielmann and associates (1983) provides useful information. In that study a program of nutritional supplements, health surveillance, and nutrition education for children less than three years of age led to an increase in height by age two of about two centimeters, almost all of which took place between 12 and 24 months. The 2SLS estimates of the impact on IQ of growth during the second year of life from table 5 imply that such a program would increase IQ scores by 9–10 points. This is a greater increase than the estimates of the impacts of corn and infant formula subsidies calculated from the reduced-form estimates of table 3.

Table 7. Conditional Demand Estimates of IQ Scores: Six-Month Growth Intervals

		Two-stage least squares for different instrument sets		
Explanatory variables	OLS	Rainfall + prices	Rainfall + prices + mother's height	Rainfall + prices + mother's height and arm circumference
Birth weight (kg)	2.263***	8.810	–1.047	–2.718
	(0.635)	(9.965)	(6.073)	(4.039)
Growth 0–6 months (cm.)	0.400***	–2.176	–1.530	–1.238
	(0.118)	(1.641)	(1.259)	(0.973)
Growth 6–12 months (cm)	0.646***	4.552	1.387	1.290
	(0.151)	(2.895)	(1.622)	(1.581)
Growth 12–18 months (cm)	0.862***	5.320*	3.000	2.834
	(0.172)	(3.050)	(2.106)	(2.033)
Growth 18–24 months (cm)	1.047***	6.007***	5.171***	5.144***
	(0.175)	(1.265)	(0.908)	(0.893)
Growth 2–8 years	0.136**	1.018	0.386	0.400
	(0.068)	(0.711)	(0.461)	(0.454)
Sex (female)	1.308**	–2.352	–1.224	–1.002
	(0.547)	(2.296)	(1.728)	(1.603)
Log mother's schooling	2.966***	0.967	2.150**	2.141**
	(0.571)	(1.332)	(0.865)	(0.854)
Log father's schooling	3.723***	1.557	2.872***	2.899***
	(0.544)	(1.425)	(0.907)	(0.893)
Log value household assets	0.326*	–0.739	0.000	0.044
	(0.176)	(0.635)	(0.331)	(0.305)
R^2	0.236			
Observations	1,870	1,869	1,869	1,869
Chi–square tests				
Overidentification		8.42	16.37	16.66
Hausman (d.f. = 6)		18.91***	27.91***	28.55***
F-tests for instruments				
Growth 0–6 months		1.92***	3.04***	3.03***
Growth 6–12 months		1.18	1.67**	1.66**
Growth 12–18 months		2.34***	2.83***	2.72***
Growth 18–24 months		7.41***	7.19***	6.87***

*Significant at the 10 percent level.

**Significant at the 5 percent level.

***Significant at the 1 percent level.

Note: Standard errors are in parentheses. Parameter estimates for the 33 barangay dummy variables are not shown. Degrees of freedom for the overidentification tests are 15 in column 2, 16 in column 3, and 17 in column 4.

Source: Authors' calculations.

Of course, the simple comparison between food subsidies and the nutrition program is incomplete because it ignores the costs of the programs. A general corn subsidy would be very expensive; in 1985 the Philippines produced 3.86 million metric tons (3.96 billion kg) of corn. The cost of a 50 percent subsidy, 1.16 pesos per kg, would be about 4.5 billion pesos per year. In contrast, the cost of the early childhood nutrition program in India cost about $110 per child in 1985 U.S. dollars, which amounts to about 2,100 pesos per year (in 1985 prices). The Philippines had about 4 million children under age three in 1985, of which at most one half could be considered to be malnourished. The annual cost for such a program for all Filipino children would be about US$37 dollars per child, which would be about 2.8 billion pesos per year (again in 1985 prices).[12] If the program were limited to the half of the population that is most likely to be malnourished, the cost would be only 1.4 billion pesos. Given that the impact of this program is stronger than that of the corn subsidy, and the cost is much lower, the early childhood nutrition program appears to be the better investment. Subsidies for infant formula may also be a worthy policy, given that it is consumed only by infants. But the imprecision of the estimates in table 3 suggests further study before such a policy could be advocated.

VI. Conclusion

The purpose of this article is to examine whether malnutrition during certain periods in the lives of young children leads to substantially lower cognitive abilities later in life. This question is difficult to address even with the rich data used here. Reduced-form estimates are less likely to yield biased parameter estimates, but drawing inferences from such estimates is difficult. Estimates of conditional demand relationships are easier to interpret but are also more susceptible to the biases than can arise when using instrumental variable methods. Fortunately, the results from both approaches tell a similar story, allowing several tentative conclusions to be drawn.

First, neither the reduced-form nor the conditional demand estimates support Dobbing's claim that the most critical period is the first six months of life, nor do they support the hypothesis that prenatal nutrition is more critical than postnatal nutrition. Second, both sets of estimates suggest that the period from 18 to 24 months may be critical. This is consistent with the experimental study of Waber and others (1981). Third, reduced-form estimates, though imprecise, indicate that price subsidies for corn and infant formula could improve children's nutritional status, but a subsidy on infant formula is likely to be more cost-effective because it is better targeted to very young children. Still, neither subsidy may be cost-effective relative to programs that directly provide medical or educational services to young children. A final conclusion is more methodological in nature: the conditional demand estimates, though potentially biased, suggest that simple OLS estimates of the impact of the timing of malnutrition may be biased, perhaps because nutritional status is correlated with unobserved factors that determine cognitive development. Studies on the timing of malnutrition that ignore this methodological problem could produce very misleading results.

When considering the policy implications of our findings, substantial caution is in order. First, when we find no evidence that a particular period of time dur-

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[12] The $110 cost is spread out over three years of participation, so the annual cost is one third of this, which is about $37.

ing early childhood is critical, we cannot conclude that malnutrition during that period has no consequences for cognitive development. Indeed, the reduced-form estimates were imprecise and at times difficult to interpret, and the standard errors of the conditional demand estimates for time periods that were not statistically significant were quite large. Rather, we claim simply that these effects may not be as important as those of other time periods.

Second, these findings are based on one area of one developing country; further evidence is needed from other countries before we can claim that the second year of life is the most critical. Third, even if the effects of malnutrition on cognitive development are strongest in the second year of life, the cost of preventing such malnutrition must be compared to the cost of preventing it at earlier or later periods, because interventions at other periods may have much lower costs. What can be said is that malnutrition policies and programs should seriously consider components aimed at reducing malnutrition during the second year of life. Fourth, if a nutritional intervention in one time period does not increase growth until some future period, the optimal time for nutritional interventions may not correspond to the critical periods identified. However, our reading of the nutrition literature (for example, Bundy 1997) is that nutritional interventions in early childhood do lead to immediate increases in child growth.

In sum, the results of this study suggest that malnutrition during early childhood can reduce cognitive performance later in life, but they do not support claims by observers that certain time periods are critical. Much more research on the impact of early childhood nutrition on cognitive development and on educational outcomes is needed to better understand the nature of these relationships. The more these relationships are understood, the better will be our ability to design effective policies and programs to reduce the negative impacts of early childhood malnutrition on subsequent school performance and, more generally, on the quality of life.

(*Appendix tables begin on the following page*)

Appendix. First-Stage Estimates of Child Nutrition

Table A1. First Stage Estimates for Table 5, Rainfall and Price Variables Only

Explanatory variables	Birth weight	Growth 0–12 months	Growth 12–24 months	Growth 2–8 years
Sex (female)	–57.057	–1.056	0.087	1.360
	(–3.18)	(–9.31)	(1.02)	(7.63)
Log mother's schooling	–2.224	0.456	0.343	0.297
	(–0.12)	(3.72)	(3.70)	(1.53)
Log father's schooling	16.069	0.259	0.357	0.311
	(0.87)	(2.23)	(4.06)	(1.68)
Log value HH assets	20.076	0.151	0.164	0.122
	(3.37)	(4.00)	(5.72)	(2.03)
% rainy months in first 6 months	38.706	–1.829	–0.414	0.262
	(0.57)	(–4.26)	(–1.27)	(0.39)
Rainfall 0–6 months	0.150	–0.005	–0.002	–0.006
	(0.32)	(–1.58)	(–0.75)	(–1.20)
Rainfall 6–12 months	0.083	0.002	–0.001	–0.003
	(0.19)	(0.87)	(0.30)	(–0.75)
Rainfall 12–18 months	–0.097	–0.004	–0.001	–0.006
	(–0.28)	(–1.80)	(–0.40)	(–1.64)
Rainfall 18–24 months	0.121	0.005	–0.002	0.007
	(0.35)	(2.12)	(–1.02)	(2.04)
Price bananas 0–6 months	3.520	–0.030	0.000	0.022
	(1.07)	(–1.43)	(0.02)	(0.65)
Price bananas 6–12 months	–2.863	–0.014	0.024	0.020
	(–0.54)	(–0.40)	(0.94)	(0.38)
Price bananas 12–18 months	6.916	–0.015	–0.030	–0.006
	(1.58)	(–0.54)	(–1.42)	(–0.13)
Price bananas 18–24 months	1.714	0.004	–0.002	0.044
	(0.39)	(0.13)	(–0.11)	(0.99)
Price corn 0–6 months	–1.050	–0.001	–0.000	–0.008
	(–1.34)	(–0.12)	(–0.12)	(–1.08)
Price corn 6–12 months	–0.904	0.002	–0.001	–0.002
	(–1.13)	(0.39)	(–0.13)	(–0.27)
Price corn 12–18 months	–0.314	0.009	0.002	–0.001
	(–0.41)	(1.91)	(0.64)	(–0.15)
Price corn 18–24 months	0.049	0.008	–0.007	–0.017
	(0.07)	(1.70)	(–1.94)	(–2.36)
Price formula 0–6 months	–0.098	0.001	–0.001	0.000
	(–0.28)	(0.30)	(–0.64)	(0.05)
Price formula 6–12 months	0.986	0.002	0.000	0.002
	(2.11)	(0.64)	(0.04)	(0.46)
Price formula 12–18 months	0.939	–0.005	–0.001	–0.005
	(1.76)	(–1.52)	(–0.37)	(–0.98)
Price formula 18–24 months	0.204	–0.003	–0.004	0.024
	(0.38)	(–1.00)	(–1.43)	(4.50)
Price Cerelac 0–6 months	1.254	–0.001	–0.003	–0.010
	(1.40)	(–0.12)	(–0.64)	(–1.12)
Price Cerelac 6–12 months	–1.321	0.001	0.003	0.003
	(–1.60)	(0.24)	(0.77)	(0.37)
Price Cerelac 12–18 months	1.001	0.005	0.001	0.003
	(1.41)	(1.16)	(0.28)	(0.42)
Price Cerelac 18–24 months	–1.124	0.001	0.005	–0.010
	(–1.83)	(0.20)	(1.55)	(–1.58)
R^2	0.053	0.106	0.179	0.122

Source: Authors' calculations.

TABLE A-2. First-Stage Estimates for Table 5, Rainfall and Price Variables, and Mother's Height

Explanatory variables	Birth weight	Growth 0–12 months	Growth 12–24 months	Growth 2–8 years
Sex (female)	–53.793	–1.037	0.096	1.419
	(–3.03)	(–9.24)	(1.12)	(8.18)
Log mother's schooling	–13.978	0.386	0.313	0.148
	(–0.73)	(3.18)	(3.73)	(0.78)
Log father's schooling	1.617	0.173	0.320	0.122
	(0.09)	(1.50)	(3.62)	(0.68)
Log value HH assets	17.265	0.133	0.156	0.067
	(2.93)	(3.56)	(5.46)	(1.14)
% rainy months in first 6 months	62.46	–1.683	–0.350	0.669
	(0.93)	(–3.96)	(–1.08)	(1.02)
Rainfall 0–6 months	0.095	–0.005	–0.002	–0.005
	(0.21)	(–1.67)	(–0.79)	(–1.12)
Rainfall 6–12 months	0.127	0.003	–0.001	–0.002
	(0.30)	(0.98)	(–0.25)	(–0.59)
Rainfall 12–18 months	–0.096	–0.004	–0.001	–0.005
	(–0.28)	(–1.82)	(–0.40)	(–1.48)
Rainfall 18–24 months	–0.037	0.004	–0.002	0.005
	(–0.11)	(1.74)	(–1.25)	(1.52)
Price bananas 0–6 months	3.774	–0.028	0.001	0.021
	(1.16)	(–1.36)	(0.07)	(0.66)
Price bananas 6–12 months	–3.119	–0.015	0.023	0.008
	(–0.60)	(–0.46)	(0.92)	(0.16)
Price bananas 12–18 months	6.807	–0.016	–0.030	–0.019
	(1.57)	(–0.58)	(–1.44)	(–0.44)
Price bananas 18–24 months	1.829	0.003	–0.002	0.047
	(0.42)	(0.12)	(–0.12)	(1.09)
Price corn 0–6 months	–1.009	–0.000	–0.000	–0.008
	(–1.30)	(–0.07)	(–0.09)	(–1.06)
Price corn 6–12 months	–0.816	0.002	–0.000	–0.001
	(–1.04)	(0.47)	(–0.08)	(–0.19)
Price corn 12–18 months	–0.394	0.009	0.002	–0.002
	(–0.52)	(1.86)	(0.60)	(–0.33)
Price corn 18–24 months	0.203	0.008	–0.006	–0.016
	(0.29)	(1.91)	(–1.84)	(–2.29)
Price formula 0–6 months	–0.168	0.000	–0.001	–0.001
	(–0.49)	(0.13)	(–0.73)	(–0.26)
Price formula 6–12 months	0.777	0.001	–0.000	–0.001
	(1.68)	(0.27)	(–0.17)	(–0.24)
Price formula 12–18 months	0.809	–0.006	–0.001	–0.007
	(1.54)	(–1.75)	(–0.50)	(–1.30)
Price formula 18–24 months	0.074	–0.004	–0.004	0.022
	(0.14)	(–1.23)	(–1.55)	(4.29)
Price Cerelac 0–6 months	1.491	0.001	–0.002	–0.008
	(1.68)	(0.12)	(–0.51)	(–0.86)
Price Cerelac 6–12 months	–1.342	0.001	0.003	0.004
	(–1.65)	(0.23)	(0.77)	(0.49)
Price Cerelac 12–18 months	0.834	0.004	0.001	0.000
	(1.19)	(0.96)	(0.16)	(0.06)
Price Cerelac 18–24 months	–1.119	0.001	0.005	–0.010
	(–1.85)	(0.19)	(1.55)	(–1.59)
Mother's height	13.711	0.081	0.035	0.185
	(7.44)	(6.90)	(3.94)	(10.26)
R^2	0.078	0.126	0.185	0.169

Source: Authors' calculations.

Table A-3. First-Stage Estimates for Table 5, Rainfall, Prices, and Mother's Height and Arm Circumference

Explanatory variables	Birth weight	Growth 0–12 months	Growth 12–24 months	Growth 2–8 years
Sex (female)	–55.615	–1.037	0.095	1.414
	(–3.18)	(–9.23)	(1.11)	(8.17)
Log mother's schooling	–14.801	0.387	0.313	0.152
	(–0.78)	(3.18)	(3.37)	(0.81)
Log father's schooling	–3.452	0.176	0.318	0.100
	(–0.19)	(1.52)	(3.60)	(0.56)
Log value HH assets	11.822	0.136	0.154	0.047
	(2.02)	(3.62)	(5.36)	(0.80)
% rainy months in first 6 months	66.909	–1.685	–0.349	0.680
	(1.01)	(–3.96)	(–1.07)	(1.04)
Rainfall 0–6 months	0.126	–0.005	–0.002	–0.005
	(0.28)	(–1.68)	(–0.79)	(–1.07)
Rainfall 6–12 months	0.203	0.003	–0.000	–0.002
	(0.48)	(0.96)	(–0.24)	(–0.55)
Rainfall 12–18 months	–0.029	–0.004	–0.001	–0.005
	(–0.09)	(–1.83)	(–0.39)	(–1.40)
Rainfall 18–24 months	–0.016	0.004	–0.002	0.005
	(–0.05)	(1.73)	(–1.25)	(1.58)
Price bananas 0–6 months	3.318	–0.028	0.001	0.019
	(1.04)	(–1.34)	(0.06)	(0.59)
Price bananas 6–12 months	–3.717	–0.015	0.023	0.004
	(–0.72)	(–0.45)	(0.91)	(0.08)
Price bananas 12–18 months	6.581	–0.016	–0.030	–0.019
	(1.54)	(–0.58)	(–1.45)	(–0.45)
Price bananas 18–24 months	0.945	0.004	–0.003	0.045
	(0.22)	(0.14)	(–0.13)	(1.04)
Price corn 0–6 months	–0.891	–0.000	–0.000	–0.008
	(–1.17)	(–0.08)	(–0.08)	(–1.01)
Price corn 6–12 months	–0.963	0.002	–0.000	–0.002
	(–1.24)	(0.49)	(–0.10)	(–0.23)
Price corn 12–18 months	–0.281	0.009	0.002	–0.002
	(–0.38)	(1.84)	(0.61)	(–0.26)
Price corn 18–24 months	0.206	0.008	–0.006	–0.015
	(0.30)	(1.91)	(–1.84)	(–2.26)
Price formula 0–6 months	–0.126	0.000	–0.001	–0.001
	(–0.37)	(0.12)	(–0.72)	(–0.25)
Price formula 6–12 months	0.648	0.001	–0.000	–0.002
	(1.42)	(0.30)	(–0.19)	(–0.34)
Price formula 12–18 months	0.780	–0.006	–0.001	–0.007
	(1.51)	(–1.74)	(–0.50)	(–1.31)
Price formula 18–24 months	0.082	–0.004	–0.004	0.022
	(0.16)	(–1.23)	(–1.55)	(4.30)
Price Cerelac 0–6 months	1.527	0.001	–0.002	–0.007
	(1.75)	(0.11)	(–0.50)	(–0.80)
Price Cerelac 6–12 months	–1.379	0.001	0.003	0.004
	(–1.72)	(0.24)	(0.76)	(0.48)
Price Cerelac 12–18 months	0.925	0.004	0.001	0.001
	(1.34)	(0.95)	(0.17)	(0.10)
Price Cerelac 18–24 months	–1.187	0.001	0.005	–0.010
	(–1.99)	(0.20)	(1.54)	(–1.66)
Mother's height	11.117	0.082	0.034	0.176
	(6.03)	(6.92)	(3.78)	(9.65)
Mother's arm circumference	30.520	–0.018	0.011	0.106
	(8.14)	(–0.73)	(0.57)	(2.79)
R^2	0.106	0.126	0.185	0.173

Source: Authors' calculations.

TABLE A-4. First-Stage Estimates for Table 5, Rainfall and Price Variables Only

Explanatory variables	Growth 0–6 months	Growth 6–12 months	Growth 12–18 months	Growth 18–24 months
Sex (female)	–0.968	–0.093	0.132	–0.040
	(–9.84)	(–1.19)	(1.97)	(–0.61)
Log mother's schooling	0.217	0.235	0.183	0.152
	(2.05)	(2.80)	(2.52)	(2.17)
Log father's schooling	0.161	0.094	0.238	0.125
	(1.59)	(1.18)	(3.45)	(1.87)
Log value HH assets	0.044	0.105	0.102	0.060
	(1.35)	(4.07)	(4.59)	(2.78)
% rainy months in first 6 months	–1.179	–0.627	0.567	–0.974
	(–3.17)	(–2.13)	(2.23)	(–3.96)
Rainfall 0–6 months	–0.003	–0.001	0.001	–0.003
	(–1.27)	(–0.53)	(0.64)	(–1.65)
Rainfall 6–12 months	0.002	0.000	0.002	–0.002
	(0.74)	(0.16)	(0.93)	(–1.49)
Rainfall 12–18 months	–0.005	0.002	–0.002	0.001
	(–2.80)	(1.03)	(–1.39)	(0.75)
Rainfall 18–24 months	0.003	0.001	0.002	–0.004
	(1.77)	(0.89)	(1.43)	(–2.85)
Price bananas 0–6 months	–0.022	–0.009	0.014	–0.012
	(–1.21)	(–0.60)	(1.15)	(–1.03)
Price bananas 6–12 months	–0.015	0.002	0.019	0.011
	(–0.52)	(0.07)	(0.92)	(0.55)
Price bananas 12–18 months	–0.044	0.028	–0.026	–0.001
	(–1.84)	(1.45)	(–1.57)	(–0.07)
Price bananas 18–24 months	0.005	–0.003	0.014	–0.013
	(0.23)	(–0.17)	(0.84)	(–0.81)
Price corn 0–6 months	–0.009	0.008	–0.004	0.004
	(–2.07)	(2.45)	(–1.51)	(1.39)
Price corn 6–12 months	–0.002	0.004	–0.000	–0.000
	(–0.50)	(1.11)	(–0.11)	(–0.05)
Price corn 12–18 months	0.007	0.003	0.001	0.002
	(1.61)	(0.78)	(0.26)	(0.65)
Price corn 18–24 months	0.003	0.005	–0.003	–0.004
	(0.72)	(1.58)	(–1.20)	(–1.46)
Price formula 0–6 months	0.000	0.001	0.002	–0.003
	(0.13)	(0.34)	(1.40)	(–2.36)
Price formula 6–12 months	0.002	0.000	0.003	–0.003
	(0.76)	(0.05)	(1.80)	(–1.93)
Price formula 12–18 months	–0.005	0.000	0.001	–0.002
	(–1.77)	(0.07)	(0.37)	(–0.84)
Price formula 18–24 months	–0.003	–0.001	0.001	–0.004
	(–0.92)	(–0.44)	(0.29)	(–2.13)
Price Cerelac 0–6 months	0.005	–0.005	–0.007	0.003
	(0.96)	(–1.38)	(–1.91)	(1.02)
Price Cerelac 6–12 months	0.004	–0.002	0.002	0.002
	(0.84)	(–0.65)	(0.56)	(0.53)
Price Cerelac 12–18 months	0.007	–0.002	0.006	–0.005
	(1.87)	(–0.58)	(2.11)	(–1.87)
Price Cerelac 18–24 months	–0.001	0.002	–0.002	0.007
	(–0.23)	(0.68)	(–1.08)	(3.15)
R^2	0.081	0.066	0.124	0.138

Source: Authors' calculations.

TABLE A-5. First-Stage Estimates for Table 7, Rainfall and Price Variables, and Mother's Height

Explanatory variables	Growth 0–6 months	Growth 6–12 months	Growth 12–18 months	Growth 18–24 months
Sex (female)	–0.956	–0.086	0.138	–0.037
	(–9.77)	(–1.11)	(2.06)	(–0.57)
Log mother's schooling	0.173	0.212	0.161	0.143
	(1.63)	(2.52)	(2.22)	(2.04)
Log father's schooling	0.105	0.065	0.211	0.114
	(1.05)	(0.81)	(3.05)	(1.69)
Log value HH assets	0.033	0.099	0.097	0.058
	(1.02)	(3.83)	(4.35)	(2.67)
% rainy months in first 6 months	–1.086	–0.576	0.612	–0.956
	(–2.93)	(–1.96)	(2.41)	(–3.88)
Rainfall 0–6 months	–0.003	–0.001	0.001	–0.003
	(–1.33)	(–0.56)	(0.61)	(–1.66)
Rainfall 6–12 months	0.002	0.000	0.002	–0.002
	(0.82)	(0.21)	(0.98)	(–1.47)
Rainfall 12–18 months	–0.005	0.002	–0.002	0.001
	(–2.81)	(1.03)	(–1.39)	(0.75)
Rainfall 18–24 months	0.003	0.001	0.002	–0.004
	(1.48)	(0.69)	(1.22)	(–2.94)
Price bananas 0–6 months	–0.021	–0.008	0.015	–0.012
	(–1.15)	(–0.55)	(1.20)	(–1.01)
Price bananas 6–12 months	–0.016	0.001	0.018	0.010
	(–0.56)	(0.04)	(0.90)	(0.54)
Price bananas 12–18 months	–0.045	0.027	–0.026	–0.001
	(–1.88)	(1.44)	(–1.59)	(–0.08)
Price bananas 18–24 months	0.005	–0.003	0.014	–0.013
	(0.22)	(–0.17)	(0.84)	(–0.82)
Price corn 0–6 months	–0.009	0.008	–0.004	0.004
	(–2.04)	(2.48)	(–1.48)	(1.41)
Price corn 6–12 months	–0.002	0.004	–0.000	–0.000
	(–0.43)	(1.16)	(–0.06)	(–0.04)
Price corn 12–18 months	0.007	0.002	0.001	0.002
	(1.57)	(0.75)	(0.22)	(0.63)
Price corn 18–24 months	0.003	0.005	–0.003	–0.004
	(0.87)	(1.68)	(–1.11)	(–1.42)
Price formula 0–6 months	–0.000	0.000	0.002	–0.003
	(–0.01)	(0.25)	(1.32)	(–2.40)
Price formula 6–12 months	0.001	–0.000	0.003	–0.003
	(0.47)	(–0.14)	(1.61)	(–2.01)
Price formula 12–18 months	–0.006	–0.000	0.001	–0.002
	(–1.95)	(–0.05)	(0.26)	(–0.89)
Price formula 18–24 months	–0.003	–0.001	0.000	–0.004
	(–1.08)	(–0.55)	(0.18)	(–2.18)
Price Cerelac 0–6 months	0.006	–0.005	–0.006	0.004
	(1.15)	(–1.26)	(–1.80)	(1.08)
Price Cerelac 6–12 months	0.004	–0.002	0.002	0.002
	(0.83)	(–0.65)	(0.55)	(0.53)
Price Cerelac 12–18 months	0.007	–0.002	0.005	–0.005
	(1.71)	(–0.69)	(2.01)	(–1.92)
Price Cerelac 18–24 months	–0.001	0.002	–0.002	0.007
	(–0.25)	(0.67)	(–1.09)	(3.15)
Mother's height	0.052	0.028	0.025	0.010
	(5.10)	(3.44)	(3.57)	(1.52)
R^2	0.092	0.071	0.129	0.139

Source: Authors' calculations.

Table A-6. First-Stage Estimates for Table 7, Rainfall Prices, and Mother's Height and Arm Circumference

Explanatory variables	Growth 0–6 months	Growth 6–12 months	Growth 12–18 months	Growth 18–24 months
Sex (female)	–0.953	–0.087	0.138	–0.037
	(–9.75)	(–1.12)	(2.05)	(–0.58)
Log mother's schooling	0.173	0.211	0.161	0.143
	(1.63)	(2.51)	(2.22)	(2.03)
Log father's schooling	0.112	0.061	0.209	0.113
	(1.12)	(0.76)	(3.03)	(1.69)
Log value HH assets	0.039	0.096	0.096	0.057
	(1.20)	(3.67)	(4.25)	(2.63)
% rainy months in first 6 months	–1.092	–0.574	0.613	–0.955
	(–2.95)	(–1.95)	(2.41)	(–3.88)
Rainfall 0–6 months	–0.003	–0.001	0.001	–0.003
	(–1.35)	(–0.55)	(0.61)	(–1.66)
Rainfall 6–12 months	0.002	0.000	0.002	–0.002
	(0.78)	(0.23)	(0.99)	(–1.46)
Rainfall 12–18 months	–0.005	0.002	–0.002	0.001
	(–2.85)	(1.06)	(–1.37)	(0.76)
Rainfall 18–24 months	0.003	0.001	0.002	–0.004
	(1.47)	(0.69)	(1.22)	(–2.94)
Price bananas 0–6 months	–0.020	–0.008	0.015	–0.012
	(–1.12)	(–0.58)	(1.19)	(–1.01)
Price bananas 6–12 months	–0.015	0.000	0.018	0.010
	(–0.53)	(0.02)	(0.89)	(0.54)
Price bananas 12–18 months	–0.045	0.027	–0.026	–0.001
	(–1.86)	(1.42)	(–1.60)	(–0.08)
Price bananas 18–24 months	0.006	–0.004	0.014	–0.013
	(0.27)	(–0.20)	(0.82)	(–0.82)
Price corn 0–6 months	–0.009	0.009	–0.004	0.004
	(–2.07)	(2.50)	(–1.47)	(1.41)
Price corn 6–12 months	–0.002	0.004	–0.000	–0.000
	(–0.40)	(1.14)	(–0.08)	(–0.04)
Price corn 12–18 months	0.006	0.003	0.001	0.002
	(1.53)	(0.77)	(0.23)	(0.63)
Price corn 18–24 months	0.003	0.005	–0.003	–0.004
	(0.87)	(1.68)	(–1.11)	(–1.42)
Price formula 0–6 months	–0.000	0.000	0.002	–0.003
	(–0.03)	(0.27)	(1.33)	(–2.40)
Price formula 6–12 months	0.001	–0.000	0.003	–0.003
	(0.53)	(–0.18)	(1.59)	(–2.02)
Price formula 12–18 months	–0.006	–0.000	0.000	–0.002
	(–1.94)	(–0.06)	(0.25)	(–0.89)
Price formula 18–24 months	–0.003	–0.001	0.000	–0.004
	(–1.09)	(–0.54)	(0.18)	(–2.18)
Price Cerelac 0–6 months	0.006	–0.005	–0.006	0.004
	(1.14)	(–1.26)	(–1.79)	(1.08)
Price Cerelac 6–12 months	0.004	–0.002	0.002	0.002
	(0.84)	(–0.66)	(0.55)	(0.53)
Price Cerelac 12–18 months	0.007	–0.002	0.005	–0.005
	(1.69)	(–0.67)	(2.02)	(–1.92)
Price Cerelac 18–24 months	–0.001	0.002	–0.003	0.007
	(–0.22)	(0.66)	(–1.09)	(3.14)
Mother's height	0.055	0.026	0.024	0.010
	(5.32)	(3.19)	(3.41)	(1.47)
Mother's arm circumference	–0.036	0.020	0.008	0.003
	(–1.70)	(1.20)	(0.59)	(0.19)
R^2	0.094	0.072	0.129	0.139

Source: Authors' calculations.

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