Revisiting the Nature vs. Nurture Debate: Patterns of Cognitive Development of Filipino Children

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Abstract

Using the QIDS panel dataset collected in 2003 and 2007, we analyze the determinants of cognitive abilities among Filipino children. We are interested in distinguishing between the effects of the learning and family environment versus health and nutrition in children aged 6 months to 7 years. Cognitive abilities are measured using the Bayley Scales of Infant Development and the Wechsler Preschool and Primary Scale of Intelligence. The home learning environment is assessed using the Home Observation for Measurement of the Environment. Health and nutrition markers include weight-for-age, height-for-age, hemoglobin and lead levels in blood. Employing a child fixed effects model, we find that the home learning environment has a significant positive effect on cognitive ability explaining more than one fourth of the standard deviation of cognitive development. Nutrition markers, particularly, weight-for-age and hemoglobin levels in blood also have significant positive effects on cognitive ability. Genetic predisposition and other time-invariant traits explain roughly 40 percent of the variation in cognitive ability. A one standard deviation increase in the home learning environment explains 30.4 percent of the standard deviation in cognitive ability whereas a one standard deviation increase in weight-for-age explains another 8.9 percent. Our results indicate that parental inputs or nurture can compensate for weak preconditions and foster cognitive development among young children.

1. Introduction

We revisit a question asked time and again: to what extent are intellectual abilities of children environmentally determined by early life experiences versus predetermined genetically? This is particularly important for disadvantaged children with below average cognitive abilities raising the question whether interventions can be implemented that either change their genetic predisposition or the learning environment. Clearly, cognitive ability is partly innate and argues for interventions that come prior to birth via antenatal care for women with the benefits being transmitted to the children intrauterine, e.g., the provision of micro-nutrients that are known to foster brain development (Ashworth and Antipatis, 2001; McArdle and Ashworth, 1999). However, if at least some variation in cognitive abilities is caused by environmental factors, then policy has a critical role promoting children's cognitive development and long-term socioeconomic success (Heckman 2008). The form and timing of interventions could be strongly influenced by what we know about the nature of development of cognitive abilities.

This paper examines the interaction of nature and nurture in the emergence of cognitive skills in early childhood from a panel of Filipino children. By "nature", we refer to traits that are shaped by a child's genetic endowment including innate ability, and other factors that are time-invariant. On the other hand, by "nurture", we refer to time-varying parental inputs, whose outcomes can be measured in terms of the quality of the home learning environment as well as health and nutrition investments, which can be measured with biomarkers. Understanding the differential impact of nature and nurture on child cognitive development is particularly important in developing countries where resources are scarce and investments in human capital compete with many other priorities such as infrastructure and financial market development.

Few studies on cognitive outcomes have been able to sufficiently control for individual unobserved heterogeneity, including genetic endowment (Rosenzweig and Wolpin, 1994). If cognitive outcomes are determined by unobserved genetic endowment, then an omitted variables problem is introduced causing the effects of other observed inputs such as schooling to be overstated (Todd and Wolpin, 2003). Early investigators addressed these identification problems using data from monozygotic twins to control for unmeasured ability and genetic endowment (Behrman and Taubman, 1976; Rosenzweig and Wolpin, 1980). This approach, however, is costly and impractical in developing countries where twin registries are not available. A less costly approach would be to use data from siblings (Rosenzweig and Wolpin, 1994) although studies on siblings do not fully deal with unobserved parental preferences, which vary across children. An eldest son, for example, might be preferred because he is the heir or a youngest daughter might get special attention because she is so charming.

Socio-economic characteristics such as poverty and household structure are correlates of cognitive ability and must be considered (Brooks-Gunn and Duncan, 1997). A host of existing studies has shown that parental nurturing is an important determinant of cognitive outcomes (Anger et al. 2009; Parker et al., 1999). The home learning environment is where parents most intimately provide for their children (Fernald et al., 2011; Melhuish et al. 2008a; Melhuish et al. 2008b). Thus, a more challenging methodological constraint that needs to be overcome is to find the proper metric for the learning environment. Existing studies fail to account for these, possibly, more important environmental factors such as language stimulation and parental care. These factors are not necessarily determined by poverty and can be provided even in resource-constrained households. For example, the time caregivers spend talking to the children and playing with them or the acceptance that is provided for the child. From a policy perspective, it is important to assess the impact of such aspects of the learning environment to understand how healthy and able children could be raised optimally even in relatively poor settings.

In addition to positive and cognitively stimulating parenting, child health and nutrition are critical links to cognitive outcomes (Behrman, 1993). This link, by contrast to the learning environment, has been relatively well studied in resource-poor settings. For example, several papers use data on Filipino children who were surveyed under the Cebu Longitudinal Health and Nutrition Study (CLHNS) (Mendez and Adair, 1999). Analyzing the relationship between early infancy stunting –a long-term nutritional marker– and cognitive development at ages 8 and 11, researchers found that Filipino children, stunted during the first two years of life, had significantly lower test scores for cognitive ability than their non-stunted counterparts, while controlling for socio-economic variables such as household income, maternal and paternal education, and place of living. The impact was found to be most pronounced for children with severe stunting but the negative impact of stunting diminished over time. Another study using the CLHNS dataset, examined the effects of the timing of malnutrition on cognitive development (Glewwe and King, 2001). Based on their OLS estimates, one could conclude that children's cognitive development at age eight is negatively affected by poor nutrition during infancy. However, in an alternative specification, they estimate a model using instrumental variables that included rainfall and prices, mother's height and upper-arm circumference. The instrumental variables estimates indicate that malnutrition in the second year of life has a larger negative impact than malnutrition in the first year of life. They concluded that the evidence of nutrition effects for early periods in childhood (first six months) on cognition in later periods is not robust and pointed to considerable identification challenges (Glewwe and King, 2001). First, the quality of the local educational environment could not fully be observed. Second, parental preferences cannot be controlled for, and third, they cannot fully account for genotype. Moreover, although they used an instrumental variable approach, the instruments themselves might also introduce bias and the coefficient estimates are likely to be imprecise. In another study, also employing the CLHNS dataset, the nutrition-learning nexus was further analyzed for pairs of siblings (Glewwe et al., 2001). Controlling for unobservables such as common heredity, environment and shared family experiences of siblings, they demonstrated that well-nourished children enter school earlier, and thus, have more time to learn and greater learning productivity per year of schooling.

To address unobserved child heterogeneity and the concomitant bias in the estimated effects of child health and nutrition on cognitive outcomes, we used a child panel dataset from the Quality Improvement Demonstration Study (QIDS) allowing us to derive within child estimates. The panel data were collected from 627 Filipino children who participated in a cognitive development test in 2003/04 and again in 2006/07. For infants and toddlers aged 6 months to 2.5 years, cognitive development is measured by the Bayley Scale of Infant Development (BSID) and for children above 2.5 years up to the age of 7 the Wechsler Preschool and Primary Scale of Intelligence (WPPSI) was used. Accordingly, every child has two age-specific measurements of cognitive development. By employing child-fixed effects models, we attempt to disentangle the impacts of time-invariant unobserved traits including those genetically transmitted and the time-varying behavioral patterns and choices made by parents. Health and educational inputs are two of the most important areas of parental intervention in a child's cognitive development (Melhuish 2010; Nyaradi 2013). The quality of educational inputs in the home environment is assessed by the Home Observation for Measurement of the Environment (HOME, see Caldwell and Bradley, 2003), and nutrition and health outcomes are measured by weight-for-age, height-for-age, the blood level of hemoglobin and elevated lead. Our model estimates provide insights on fundamental questions on child development: Are there natural limits to a child's cognitive development imposed by one's genetic make-up? And how much can parents do to enhance the cognitive development of their children?

Four results stand out. First, "nature", roughly measured as child-fixed effects, explains more than 40 percent of the variation in children's cognitive performance. The joint explanatory power of the remaining control variables is below 15 percent. This finding demonstrates the large role stable predispositions have on cognitive skill formation. At the same time, this shows that even individuals with relatively low levels of intrinsic ability have a significant amount of cognitive variation that might be fostered and stimulated. Second, we confirmed this observing that the quality of the home learning environment has a large positive impact on cognitive development: a one point increase in the score associated with the home learning environment leads to roughly half a point increase in the cognitive development score. This suggests that the home environment created by the parents has a big role in facilitating the cognitive development of their children. Third, normal levels of hemoglobin are positively associated with cognitive ability. Contemporaneous weight-for-age (wasting) is positively associated with cognitive development whereas contemporaneous height-for-age (stunting) has no effect. We interpret the biologic and anthropometric data to reflect the importance of contemporaneous nutrition for mental activity and cognitive development. Fourth, due to the use of child-fixed effects, guardian characteristics such as gender and the level of education do not impact the child's performance in the test because these have little variation over time. These guardian characteristics would vary only when the guardian changes, as in the case of parents leaving the home for overseas employment or marriages breaking up. However, we note that the presence of grandparents and other old people living in the household seems to have a positive and significant role in stimulating the minds of young children.

The paper is organized as follows: Section 2 outlines the theoretical framework while Section 3 presents the empirical model. Section 4 describes the data set including the measures of cognitive development and the home learning environment and provides the descriptive statistics. The results are presented in Section 5, and Section 6 concludes.

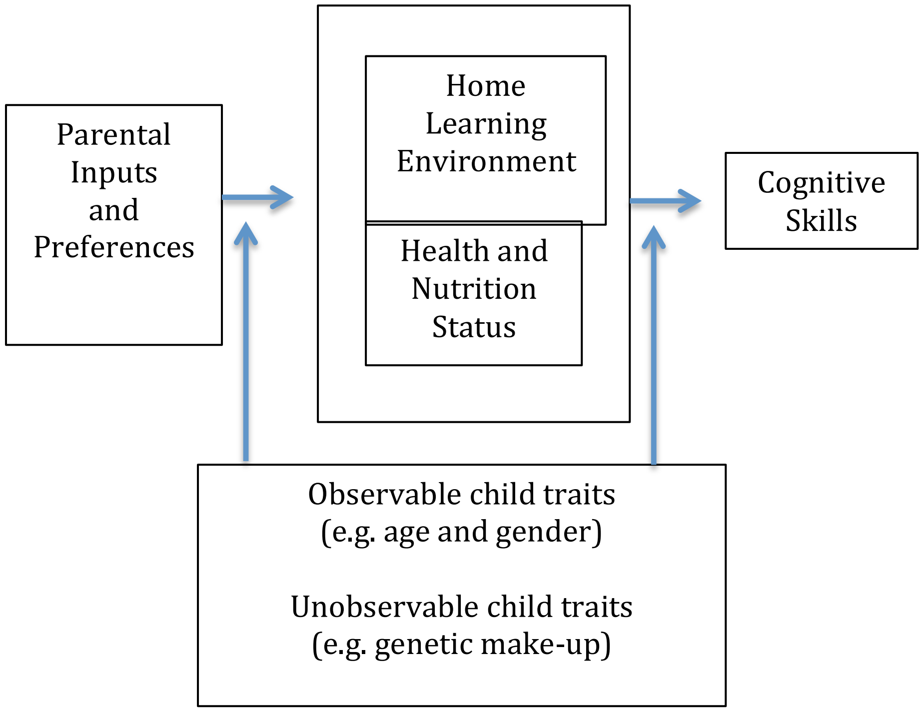
2. Theoretical Framework

Cognitive ability is broadly defined as all mental abilities related to knowledge formation. It is physically embodied in cognitive skills, which can be produced according to the following function:

$$C_t = f(E_t, N_t, Ch_t, H_t; C^0, \eta) \quad (1)$$

where C is a measure of cognitive ability and its initial stock is denoted with a superscript 0. E measures the quality of the home learning environment, N refers to the child's health and nutrition status, Ch are other child-specific observed traits affecting cognition such as age and gender, and H are household characteristics such as composition and size. E, N, Ch, and H capture contemporaneous effects on cognitive outcomes, where the subscript t refers to time. On the other hand, η refers to unobserved traits affecting cognition, including the genetic endowment or innate ability. Both the home learning environment and nutritional inputs result from parental investments in terms of time and resources. We assume that all inputs have a positive marginal product on cognitive performance: $f'_E>0, f'_N>0, f'_{Ch}>0$ and $f'_H>0$ and all marginal products are subject to diminishing returns. Our model builds on the skill formation technology presented in Cunha and Heckman (2007) and Cunha and Heckman (2010). Figure 2 schematically represents the cognitive skill formation process. Parental inputs and preferences generate the home environment E and shape the health and nutrition status N of the children leading ultimately to the production of cognitive skills. Yet, the process is influenced by observable (Ch) and unobservable (η) child characteristics. The latter also captures genetic make-up.

Figure 2. Schematic Diagram of the Cognitive Skills Production Function



3. Empirical Model

The empirical model focuses on the production technology for cognitive skills. We impose a linear structure on the skill production function for every child i at time t:

$$C_{it} = \alpha_0 + \alpha_1\, Home_{it} + \alpha_2\, Health_{it} + \alpha_3\, Child_{it} + \alpha_4\, HH_{it} + \lambda_t + \eta_i + \varepsilon_{it}$$

where C_{it} is a measure for cognitive skills resulting from a standard test. $Home_{it}$ measures the quality of the home learning environment. The health indicators are collected in $Health_{it}$. These include weight-for-age as a suitable proxy for nutrition and height-for-age as proxy for accumulated child health, say the child health stock. Both are measured in terms of standard deviations relative to the WHO reference population. In addition, we include a dummy variable equal to 1 whenever the child has a normal level of hemoglobin and another dummy variable equal to 1 whenever elevated lead (lead> 10 micrograms per deciliter) is found in the child's blood sample. The vector $Child_{it}$ denotes time varying child characteristics such as age. Although the cognitive development, the weight and height measurements are age adjusted we include the child's age in months as control variable to ensure that age dynamics are fully captured. We further include an indicator variable that is equal to 1 in the baseline survey if the child initially took the Bayley Scale of Infant Development (BSID) test. We include this variable to account for any differences that remain between BSID and the Wechsler Preschool and Primary Scale of Intelligence (WPPSI) after the age-adjustment. HH_{it} is a vector of household characteristics including guardian characteristics such as gender and years of education of the primary caregiver. In addition to guardian characteristics, we also include household demographics such as size and the dependency ratio for the children who are up to 14 years old and the elderly who are 65 or older. Last, we control for a round effect λ_t and the child fixed effect η_i. We allow child observations to be correlated in an unknown fashion and account for it by clustering the standard error, ε_{it}, at the child level.

We initially considered specifying our empirical model in first differences instead of levels. This implies that the bias resulting from the correlation between the time-invariant characteristics - say a child's genotype - and the nurture inputs, such as nutrition and the creation of a quality home environment, is removed (Kirchberger, 2008). With the difference form, however, all child-fixed effects are removed and coefficients for time-invariant variables such as gender and the initial level of skills cannot be estimated. In addition, a difference specification does not allow us to assess the joint explanatory power of a child's time-invariant characteristics on cognitive skills. We thus resort to a child-fixed effects model to estimate the extent of the role of intrinsic ability in cognitive development. In related work, others have used child-fixed effects estimators to address the potential endogeneity of childcare choices (Resul et al., 2010). The fixed effects model allows the estimation of the effects of time-varying heterogeneity such as that resulting from parenting preferences. This is important because, contrary to existing studies, we have time-varying information to control for the home learning environment. We consider the home environment and health and nutrition status as a proxy for parental attitudes towards the child.

4. Data

We utilized repeated measures of cognitive development and child health from the Quality Improvement Demonstration Study (QIDS). QIDS, which was implemented in the the Philippines from 2003 to 2008 (Shimkhada et al. 2008), was a large randomized policy experiment that took place in 30 public hospitals and involved over 6000 children throughout the central regions (the middle one-third) of the country. The main purpose of QIDS was to evaluate the impact of two policies —one designed to improve the quality of clinical care using payment incentives to doctors versus an expanded health insurance alternative to improve access to care—on the health status of children age 6 months up to five years in age. The health status outcome measures, along with the socioeconomic covariants, in QIDS were broad ranging from anthropometrics, physiological assessments, blood tests and notably the cognitive development of children (Quimbo et al., 2011, Peabody et al., 2014).

In this study, we used the QIDS two rounds of data collected from the children and their parents in the baseline cohort. The children were identified at the time of discharge from one of the QIDS hospitals and interviewed in their home 4-6 weeks after being discharged; they were re-interviewed 2 years after the initial survey. During both the initial and follow-up interviews, the children were administered age-appropriate psychological tests, namely, the Bayley Scale of Infant Development (BSID) and Wechsler Preschool and Primary Scale of Intelligence (WPPSI). By using the baseline panel of children, none of them directly benefitted from the QIDS experiment. Thus, we are not able to assess the impact of the QIDS interventions, namely, the quality of care they received in the hospitals, on their cognitive development. However, in the study at hand we can make use of the rich data on cognitive development to assess the determinants of children's cognitive abilities independently from the QIDS intervention.

The baseline cohort of children with tracer conditions pneumonia and diarrhea, consisted of a total of 1,463 patients aged 6 months to 6 years old (roughly 50 patients per study hospital) who were paid an initial follow-home visit in 2003. During both the first and second follow-home interviews, the children were asked to participate in psychological testing. Two types of tests were administered: the BSID for children aged 6 months to 2.5 years and the WPPSI for children above 2.5 years up to about 7 years. In 2006 to 2007, the second round of data collection took place. By then all children took the age-appropriate WPPSI. Of the 1,463 patients in the baseline cohort, only 627 had complete psychological test scores and correct age information in the two rounds of data collection. This subset forms the regression sample. Concerns with possible biases due to attrition are discussed in Section 5.2.

4.1 Cognitive Assessments

The Bayley Scale of Infant Development (BSID) was designed by Nancy Bayley (1993) as assessment tool of the cognitive development of infants and toddlers between 0 and 3 years. We use version II of the tool. The BSID is a mental development index combining scores on cognitive, language and personal development and represents an accredited measure of the developmental functioning of infants and toddlers used by psychologists to detect developmental delays.[1] The test is individually administered by specifically trained psychologists and takes between 45 and 60 minutes to complete. In the BSID, a series of test materials are presented to the child by the clinician and the child's responses and behaviors are observed and reported in a standardized way.[2] We make

[1] The Bayley Scale of Infant Development Version III (BSID-III) has been more recently introduced.

[2] The following types of abilities are captured by the test: (i) sensory/perceptual acuities, discriminations, and response; (ii) acquisition of object constancy; (iii) memory learning and problem solving; (iv)

use of the mental development score, which is derived from the testing. In the context of this study, the test was administered to children between the age of 6 month and 2.5 years. We obtained standardized, age-adjusted scores to have measures that are comparable across age cohorts. The average score in our sample is 88.7 and the maximum score is 149 (see Table 1). According to the BSID manual, cognitive development is considered normal if scores range between 85 and 114. Thus, the children in our sample who took the BSID are normally developed on average. The maximum score of 149 indicates that some children, with scores higher than 114, have accelerated performance.

For the older children at baseline and all children in the second interview round, we used the Wechsler Preschool and Primary Scale of Intelligence (WPPSI) tool to assess the cognitive development, which is appropriate for children aged 2.6 to 7 years. WPPSI is also an individually administered test of cognitive development used for assessing children who have outgrown the BSID tool. The WPPSI has two sets of tools —young and old— which are used for aged 2.6 to 3.11 and 4.0 to 7.3, respectively (Wechsler 2002). WPPSI has two component scores, referred to as verbal and performance. A full-scale score is derived as a summary measure of cognitive ability encompassing both the verbal and performance components. For young children, the verbal component consists of tasks measuring receptive vocabulary and information and the performance component is composed of tasks around block design and object assembly. For the older children, the verbal component combines information, vocabulary, and word reasoning. The performance score for older children adds tasks of matrix reasoning and picture concepts to block design (compare Table A1). For comparability across different versions of the test and over time, we use age-adjusted WPPSI scores in the analysis. Because the tests were done roughly 2 years apart, all of WPPSI-Young takers at baseline shifted to WPPSI-Old at follow-up. The average WPPSI score in our sample is 88.1 and indicates that the average child in the sample is found in the low average performance group ranging from a score of 80 to a score of 89. For comparison purposes, the classification of average performance starts at 90 points indicating that the sampled children are slightly lagging behind average performance levels.

For the study at hand, we combine the different test scores resulting in a cognitive development measure composed of an age-adjusted mental development index of the BSID for infants and small children, an age-adjusted WPPSI-Young score for young children and an age-adjusted WPPSI-Old score for older children. While we would prefer our analysis to rest on one single test, we are not aware of a single cognitive development test that covers the age range of 6 months up to 7 years. Moreover, as can be seen from Figure 1 the distribution of the mental development index of the BSID and the full WPPSI score overlap and the Kolmogorov-Smirnov test fails to reject the equality of distribution (p-value=0.130). Because we employ a within-child analysis of the two pathways of nature and nurture to cognitive development, we argue that combining age-adjusted test scores from different instruments can be a valid approach. Our comparison is not across cohorts but within-child. At each point of measurement, the age-adjusted score represents the development of the child at that time allowing for situations in which children who perform well during the first measurement, show a lower performance during the second test and vice versa.

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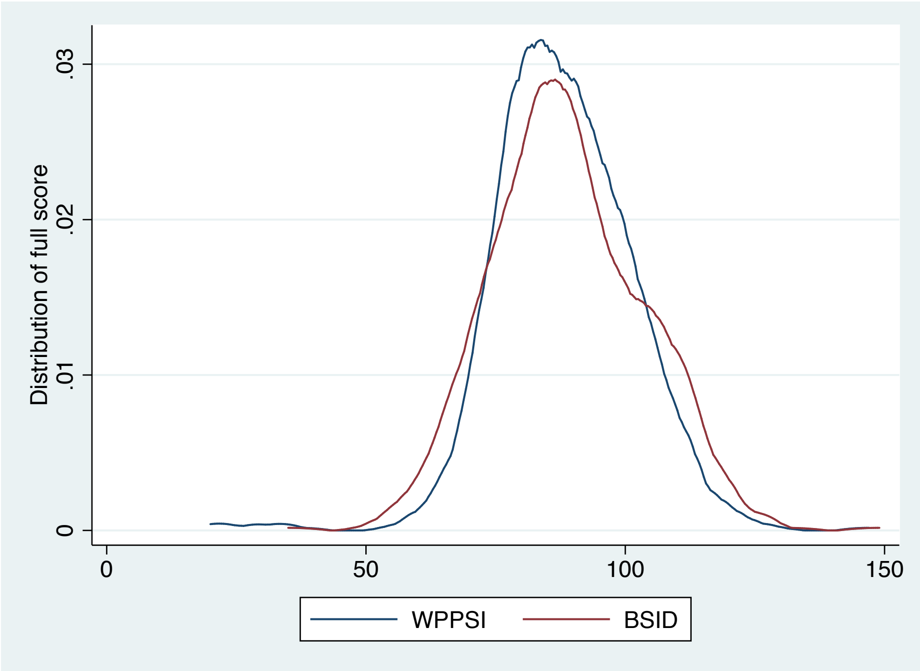
vocalization and beginning of verbal communication; (v) basis of abstract thinking; (vi) habituation; (vii) mental mapping; (viii) complex language; and (ix) mathematical concept formation.

Figure 1: Distribution of cognitive development scores, by test type



To measure a child's home learning environment, we employ the Home Observation for Measurement of the Environment (HOME) Inventory (Caldwell and Bradley 2003). This is a systematic assessment of the caring environment in which the child is brought up and is intended to measure not only the quantity but also the quality of stimulation and support available to a child in the home environment (Totsika and Slyva 2004). HOME is an established measure of child simulation in the child's normal environment that has been used for more than 40 years as it is easy to administer and score, combines the methods of interview and observation and is not threatening to the concerned family. The HOME instrument has 45 items for infants and toddlers and 55 items for children aged 3 to 6 allowing for increasing complexity as children develop. For the infants in our sample (children aged 6 months to 2.5 years) the scale consists of the following items: (i) The emotional and verbal responsivity of the primary caregiver, (ii) avoidance of restrictions and punishments such as shouting at the child, (iii) the organization of the home environment and the child's personal space, (iv) the material for play, (v) the parental involvement with the child, i.e. whether the primary caregiver tends to have an eye on the child, and (vi) stimulation by meetings with individuals other than the primary caregiver. The average HOME scale for *young* children in our sample is 29.31 out of 45 (age range covered 0-30 months). Thus 65 percent of the possible home stimulus is provided to study participants leaving room for improvement. For children in our sample that are older than 2.5 years the HOME score is clustered into eight subscales including learning materials, the home environment, vocal and physical interactions and academic stimulation.[3] The average HOME score for child observations in the age range of 31-85 months is 34.08 out of 55. For the older children only 62 percent of the possible home stimulus is achieved.

In assessing health, we rely on anthropometric and physiologic biomarkers. All sampled children were weighted and measured, which allows us to construct weight- and height-for-age Z-scores comparing the children under study to well-nourished children in the WHO reference population (World Health Organization, 2007). In addition, blood samples were taken from the children and tested for hemoglobin and lead. Hemoglobin is a measure of the number of red blood cells and carries most of the oxygen in the blood. It was shown that hemoglobin is positively associated with cognitive development (Ai et al., 2012; Paxson and Schady, 2007). Lead is a known neurotoxin and adversely affects cognitive development (Dietrich, 2000; Rice, 1988; Aizer et al., 2015). Solon et al. (2008) found, using QIDS data, that a unit increase in blood lead levels predicts a 3.32 point drop in cognitive functioning of children aged 6 months to 3 years and a 2.47 point decline in children aged 3 to 5 years old.

4.2 Descriptive Statistics

Table 1 shows the descriptive statistics. The average age-adjusted full cognitive score is 88 with baseline scores being slightly higher than follow-up scores. For the cognitive scores we observe a similar negative correlation with age as for the anthropometric Z-scores suggesting that the age-adjustment disproportionally impacts older children (Kopp and McCall, 1982). The majority of the children, namely 89.8 percent, took the BSID test in the baseline survey. When comparing the baseline scores resulting from BSID with those from WPPSI we do not find significant difference at the 1 percent level but reject equality of means at the 5 percent level. The quality of the home learning environment is represented by the HOME score. The average score is slightly below 32 and increases across survey rounds. This increase in the HOME score is built in as the learning environment of younger children is assessed on 45 items and the learning environment of older children is assessed on 55 items. The health status of the children is worse compared to children from the WHO reference population. With a weight-for-age Z-score (WAZ) of -1.22 the average child is malnourished and accumulates this bad health as shown by the even lower height-for-age Z-score (HAZ) indicator of -1.59. Despite a weakly anthropometric condition, 64.6 percent of the children have a normal hemoglobin level ranging between 10.5 and 13.5. Only 21.5 percent of the children have an elevated lead level where the cut-off for high lead was set at 10 micrograms per deciliter, which is rated as a “blood lead level of concern” according to the Centers for Disease Control and Prevention (2013).

[3] The detailed categories are (i) learning materials such as age appropriate toys, (ii) language stimulation by communicating with the primary caregiver, (iii) the larger physical environment, i.e. the family house, (iv) responsivity in the interactions between caregiver and child, i.e. the parent holds the child close for some time, (v) academic stimulation that encourages the child’s intellectual ability such as learning colors or patterned speech, (vi) modeling, which refers to the boundaries set by the parents (vii) variety between different activities such as indoor and outdoor, and (viii) acceptance demonstrated by the way the caregiver disciplines the child.

Table 1. Summary statistics for the full cognitive development score and the covariates

Variable	Total Mean	Total Std. Dev.	Baseline Mean	Baseline Std. Dev.	Follow-Up Mean	Follow-Up Std. Dev.
Cognitive development scores						
Full cognitive development score	88.356	13.923	89.297	15.483	87.416	12.104
WPPSI full score for all children taking the test	88.081	13.387				
BSID full score in round 1			88.694	14.559		
WPPSI full score in round 1			94.594	21.436		
Child took BSID in round 1	0.449	0.498	0.898	0.303		
Home learning environment	31.907	7.337	29.903	6.407	33.911	7.657
Health and nutrition indicators						
WAZ	-1.222	1.347	-0.989	1.308	-1.454	1.347
HAZ	-1.587	1.451	-1.490	1.595	-1.685	1.286
Normal hemoglobin level	0.646	0.478	0.687	0.464	0.604	0.489
High lead level	0.215	0.411	0.300	0.459	0.131	0.337
Child characteristics						
Child is male	0.581	0.494	0.581	0.494	0.581	0.494
Age in months	33.128	18.021	18.36	10.338	47.896	10.307
Guardian and household characteristics						
Guardian years of education	7.68	10.347	8.600	3.304	6.761	14.202
Female guardian	0.904	0.294	0.907	0.290	0.901	0.299
Household size	6.206	2.372	5.820	2.300	6.592	2.381
Ratio of dependents of 0-14 years	1.233	0.801	1.170	0.721	1.297	0.871
Ratio of dependents of 65+ years	0.056	0.229	0.038	0.154	0.075	0.283
Per capita household income	994.458	993.643	940.311	917.239	1048.605	1062.558

Note: The total number of observations is 1,254 corresponding to 627 observations per round. In the first round of data collection, 563 children took the BSID cognitive test and the remaining 64 took the WPPSI test.

Among household characteristics, our sample consists of slightly more male than female children (58 percent are male). The average age is 33 months with an average age of 17 months at baseline and roughly 4 years in the follow-up survey. The age-range of the participating children is from 6 to 85 months. The control variables include guardian and household characteristics such as the age and gender of the guardian, household size and composition. Almost all children have a female guardian who averaged about eight years of education. As can be seen from the slight variations in guardian characteristics across survey rounds, it is possible that a child's guardian changes. In our sample, 47 percent of the children changed guardians across survey rounds. This is a particular feature of the Philippines as many mothers work outside the country as nurses or housemates and have to leave their children with other family members. The average household consists of 6 individuals with a considerable share of young dependents relative to the working age members of the household. The share of older dependents is only 0.056 on average. Monthly per capita income ranges at roughly 995 pesos (22.5 US$) indicating that the children under study reside in poor households.[4]

5. Results

5.1 Main results

[4] The applied peso-US$ exchange rate is 0,0226.

Across regressions, the full cognitive development score (the combined WPPSI and BSID score) is the dependent variable (see Table 2, where the first column presents OLS results and columns 2 to 3, the child-fixed effects results).[5] Across specifications, the sign and significance of the key explanatory variables are similar. We highlight four key results.

First, nature, i.e. the child-fixed effects, explains more than 40 percent of the variations in children's cognitive performance whereas the joint explanatory power of the remaining control variables is below 15 percent within-child (see bottom of Table 2). This finding demonstrates the large role nature has for cognitive skill formation. Importantly, it also shows that individuals with relatively low levels of intrinsic ability can be fostered and stimulated. One important implication of this result is that parents could potentially respond to the observed ability of their children by compensating genetically disadvantaged children with health and nutrition interventions and stimulating them through a conducive home learning environment. At the same time, parents who observe that their children are very gifted could further foster their skills by nurturing their body and mind. These are specific examples of how parental preferences can be captured by changes in the home environment and health and nutrition markers.

Second, the home learning environment is highly statistically significant ($p<0.001$) and positively associated with cognitive development. Moving from the pooled OLS model to the fixed effects specification, we find that there is only a small drop in coefficient size of 0.032 (0.577-0.545). Thus an increase of 1 in the HOME score is associated with roughly half a point increase in the cognitive development test score. Put differently, a sample standard deviation increase (=7.337) in the quality of the home learning environment explains more than one fourth of the standard deviation in the cognitive development test (see Table 1). This finding confirms that parents play an important role in stimulating the cognitive development of their children and they can do so by spending time playing with the child, which is not costly. Even resource-poor households can boost the cognitive development of their children by talking to their child and providing them a protected, encouraging home environment.

Third, among the health and nutrition markers, the weight-for-age Z-score (WAZ) has greatest impact on test performance. In the child-fixed effects model (Table 2, Column 2), increasing WAZ by the sample standard deviation (=1.347 from Table 1) explains 8.85 percent of the standard deviation in the cognitive performance test scores. If the home environment and WAZ are jointly improved by their respective standard deviation as much as 37.57 percent in the variation of cognitive development can be explained. A similar positive relationship is found for children who have a normal level of hemoglobin. They score, on average, 2 points higher on the cognitive development test. This finding supports existing evidence (Ai et al. ,2011 and Paxson and Schady, 2007). We further note that the OLS model underestimates the WAZ coefficients: Given that

[5] We also employed an OLS model on each round of data separately to ensure that the patterns we find with the panel data are coherently displayed across rounds. The main results about the positive association of the home learning environment and the health indicators hold. We further detect the negative impact of age but do not find any significant impact of the guardian characteristics on cognitive skills. We do not present the results as part of our main findings as they suffer from ability bias. The authors can make them available upon request.

unobserved ability and cognitive outcomes tend to be positively correlated, we infer that the unobserved child characteristics and WAZ are negatively correlated. This is consistent with a compensation story: parents could be nurturing to "compensate" for nature by providing more or better food to children who are likely to be under-achievers because of perceived innate disadvantages. Thus, in addition to quality time spent with the children, parents should also invest in proper nutrition. While existing studies have already delineated the importance of *early childhood nutrition* for cognitive development (Wisniewski, 2010; Glewwe and King, 2001; Mendez and Adair, 1999), the study at hand underscores the necessity for continued proper nutrition.

Table 2. Regression results for the full cognitive development score

Outcome: Full cognitive development score	OLS	FE Basic model	FE with family composition
Home learning environment	0.577***	0.545***	0.554***
	(0.056)	(0.073)	(0.072)
Health indicators			
WAZ	0.762**	0.915**	0.861**
	(0.296)	(0.438)	(0.435)
HAZ	0.011	-0.600	-0.603
	(0.298)	(0.399)	(0.398)
Normal hemoglobin level	1.306*	2.019**	2.029**
	(0.745)	(1.021)	(1.027)
High lead level	-0.779	1.039	1.161
	(0.954)	(1.285)	(1.268)
Child characteristics			
Age in months	-0.360***	-0.399***	-0.411***
	(0.045)	(0.125)	(0.124)
Child took BSID in round 1	-12.115***	-8.535***	-8.620***
	(2.624)	(2.390)	(2.405)
Guardian and household characteristics			
Guardian years of education	0.020	-0.016	-0.005
	(0.025)	(0.045)	(0.047)
Female guardian	0.288	-1.501	-1.629
	(1.223)	(2.192)	(2.181)
Household size	-0.336**	1.387***	1.193**
	(0.159)	(0.491)	(0.488)
Ratio of dependents of 0-14 years			1.213
			(0.765)
Ratio of dependents of 65+ years			4.071*
			(2.133)
Per capita household income	0.000	-0.000	0.000
	(0.000)	(0.001)	(0.001)
Child FE	No	Yes	Yes
Round FE	Yes	Yes	Yes
Within variance explained by covariates		0.126	0.133
Variance explained by child FE		0.438	0.440
Joint validity of health indicators (p-value)	0.019	0.037	0.037
Hausman FE vs RE test (p-value)		0.003	

Note: Across specifications the total number of observations is 1,254 corresponding to a total number of 627 children. Standard errors are clustered at the child level. ***/**/* indicates significance at the 1/5/10 percent level, respectively.

Height-for-age, however, is not found to have a significant effect on cognitive development. While the relationship between height and intelligence has been extensively studied (Taki et al., 2012; Silventoinen et al., 2006; Sundet et al., 2005), most studies document a correlation for either adults or older children and most importantly in cross-sectional set-ups. Our results suggest that the height-intelligence link is not manifested within children over time but rather across children. Furthermore, our results underscore the importance of contemporaneous inputs for current performance, i.e., nutrition that affects current weight. Complementary evidence for our results comes from Duc (2011) who showed for a sample of Vietnamese children that the effect of HAZ at age one on cognitive skills at age five is not statistically significant once preterm length is controlled for. It is further suggested by the literature that omitting other health problems from regressions of children's test scores on health and nutrition leads to an ubward bias on stunting (Wisniewski, 2010).

We further note that previous studies showed a negative relationship between elevated lead levels in blood and cognitive performance (Aizer et al., 2015; Solon et al., 2008). However, these studies rely on cross-sectional datasets and do not control for time-invariant child characteristics. Lead is primarily found in the paint used at the house walls.[6] In this analysis it is likely that by controlling for child-fixed effects that includes quality of housing, which is typically unchanged through the survey rounds, is masking the lead effects on IQ that are reported in cross-sectional studies.

Fourth, the OLS estimates point to a negative relationship between household size and cognitive performance in contrast to the child fixed-effects models, which point to a positive impact of household size on cognition. To disentangle these, we included two more variables for household composition, namely the ratio of child dependents up to the age of 14 and the ratio of elderly dependents aged 65 and older (see Column 3 of Table 2). We find that the ratio of child dependents does not have an impact on cognitive skills whereas the ratio of elderly dependents has a positive and significant impact on cognition. This suggests a positive role for grandparents and other old people living in the household. The elderly tend not to have a regular job anymore and will be at home enriching the learning environment. They will have time to play with the children and can sing and read to the children and tell them stories. The interaction of children with older members represents an investment in the human capital of future generations that has so far not reached much attention in the literature. While they might not contribute to contemporaneous income generation, they appear to build human capital of the young in this study. In the context of Filipino households, this finding is important given that an increasing number of household heads and spouses leave their families for employment overseas leaving the children to be raised by their grandparents.

Guardian characteristics such as education and gender do not impact the child's performance in the cognitive testing. We find this in the pooled OLS as well as for the fixed effects model. One might argue that this is due to lack of variation in guardian characteristics but 47 percent of the guardians change over time suggesting that it is not the guardian *per se* who is important for a child's cognitive development but the home environment. While it seems to be of no importance that a child's primary caregiver is

[6] A supplementary survey conducted among children with elevated lead levels in blood found lead paint used on the interior and exterior walls in hospitals where they were admitted as well as in one school.

the mother, household demographics have an impact on child cognitive development. Information on guardian age, which might be another potentially important determinant of a child's cognitive development, is not available for all children under study. For a *sub-sample* of the children with information on guardian age we also include this control variable, which is similarly unrelated to a child's cognitive performance.[7] We thus decided to exclude guardian age in favor of a larger sample.

To account for the fact that some of children were taking a different test at baseline, we include a control variable for all those children who took the BSID test at baseline. The coefficient associated with this indicator variable is negative and highly statistically significant (p>0.001) across specifications indicating the importance of accounting for this difference in type of test. For completeness we also control for child age in the analysis. We find a negative relationship between age and the age-adjusted cognitive development score. This relationship echoes the one found for age and WAZ/HAZ and points to the establishment of a systematic negative relationship between age and age-adjusted scores. Others have previously argued that this is the case since over time IQ measures become more stable and more predictive (Kopp and McCall, 1982). We also control for per capita income to capture the impact of economic resources. Controlling for all the other child and household specific effects, the economic conditions do not have any additional explanatory power for child cognitive development. Results are unchanged no matter whether we include per capita income in levels or log.

5.2 Robustness checks and study limitations

Due to the high costs associated with implementing the cognitive development tests, a challenge in work with such data is sample size. This challenge is compounded in a panel dataset imposing the need for two observations per included child. Therefore, we are confronted with sample attrition. The original sample consists of 1,463 children who participated in both survey rounds. However, the psychological assessments were not completed or properly implemented for all children. In addition, the health indicators were missing for some children. Consequently, while we did not lose children to follow-up, we did lose a portion of the originally surveyed children to incomplete data. To check for bias in the missing sample, we assess the representativeness of our sample along some key explanatory variables (Table 3). Our estimation sample has a similar gender distribution, guardian characteristics, economic conditions and ratio of elderly dependents as the missing observations. There are some small differences: children in our sample tend to be 7 months younger on average; the households are slightly bigger but the difference is only 0.224; and there is a smaller ratio of young dependents with the difference being only 0.100. We do not have any evidence from our fieldwork suggesting systematic attrition but note that some households could not be tracked for the follow-up survey as they had moved outside the catchment areas. In sensitivity analysis, wherein we only use a subcomponent of the WPPSI score, we can enlarge our estimation sample by almost 100 children. In this larger analytic sample, the results established in the main paper are fully supported and balancing holds for all except one variable, the ratio of dependents of 0-14 years (see the appendix Tables A2 to A4).

[7] We do not show the results for the sake of brevity but the authors can make them available upon request.

Another possible limitation of our study is that the sampled children could be a sicker sub-population as compared to the universe of Filipino children. The children in our sample have all been admitted to a hospital four to six weeks prior to the baseline household interview because of pneumonia or diarrhea. While one has to keep in mind the selection of children into this study, we note that for this analysis, we did not have to rely on data that was collected at discharge. Moreover, from a comparison of clinical indicators at discharge versus baseline (i.e. C-reactive protein level measuring inflammation) we can conclude that the children have recovered at the time of discharge (Quimbo et al. 2010). Nonetheless, given this context, we consider our estimates as lower bounds of the possible effects of nurture on cognitive development as healthy children can potentially even benefit more from nutrition inputs and stimuli because they do not need to compensate or catch up.

Table 3: Comparison of means between estimation sample and attrited observations for the full cognitive development score

	Estimation sample			Attrited observations			Difference in means test (p-value)
	Sample size	Mean	Std. Dev.	Sample size	Mean	Std. Dev.	
Child is male	1,254	0.581	0.494	1,032	0.547	0.498	0.103
Age in months	1,254	33.128	18.021	1,032	40.371	19.752	0.000***
Self-rated health status at least good	1,254	0.837	0.369	1,032	0.828	0.377	0.573
Guardian and household characteristics							
Guardian years of education	1,254	7.680	10.347	1,028	8.120	6.635	0.239
Female guardian	1,254	0.904	0.294	1,030	0.887	0.316	0.186
Household size	1,254	6.206	2.372	1,027	5.982	2.202	0.020**
Ratio of dependents of 0-14 years	1,254	1.233	0.801	1,014	1.329	0.905	0.008***
Ratio of dependents of 65+ years	1,254	0.056	0.229	1,014	0.055	0.198	0.885
Per capita household income	1,254	994.458	993.643	1,017	1,074.060	1,368.944	0.109

Note: Comparison of means for covariates that are available in both sub-samples. ***/**/* indicates significance at the 1/5/10 percent level, respectively.

A final concern relates to the use of the cognitive development scores themselves. In most of the psychological literature these scores are used for cross-sectional cohort studies. To circumvent possible problems, we make use of age-adjusted test scores and only consider the within child development. Moreover, we work with a combination of different scores. In the main analysis, we presented results for a combination of the BSID mental development index and the WPPSI full score consisting of a combination of a verbal test score and a performance test score (compare Section 2.2). We opt for this combination of scores as the distributions are shown to be statistically identical (Figure 1). Moreover, the existing literature has shown that the mental development index of the BSID correlates with a correlation coefficient of 0.73 with the WPPSI full score (Bayley, 1993). We could have combined the BSID mental development index, of which language development is one of the key components, with only the verbal component of WPPSI. In the sensitivity analyses found in the appendix (Tables A2 to A4) we present a full set of results for this exercise. Our four key findings remain robust. However, the distributions of the BSID and the WPPSI verbal component are no longer identical (Figure A1).

Overall, we are confident that the combined results show that stable predispositions predetermine a child's potential but environmental factors can foster child development through improved child health and a quality home surrounding that stimulates the child. As part of this home environment, grandparents can play an important role in increasing the human capital of children.

6. Conclusion

We find evidence that a child's time-invariant traits including genetic skills endowment explain a substantial amount of variation in cognitive ability. Yet, time-varying parental inputs affecting the home environment and nutritional status of children also significantly influence young children's cognitive ability. This suggests that parents of children with disadvantaged predispositions can and do compensate for these by appropriate investments in human capital. Some households appear to provide their children with a better home environment and others are able to make better nutrition-related decisions. Nature is indeed an important pathway to cognitive ability, but nurture is a potential powerful compensatory mechanism and equalizer. The idea of the 'No Child Left Behind Act' established in the United States is supported by this research implying that disadvantaged children from poor families are not beyond help. They can benefit from high-quality nutrition and stimulating learning inputs that are not necessarily costly. Our findings complement earlier evidence by others who argued that a bundled intervention consisting of early education, nutrition, and health services targeted to poor children achieves improvements in cognitive development (Bitler et al. 2014).

The evidence on the potential cognitive gains from a stimulating home environment and better health to poor children continues to be scant. Mayer et al. (2015) show that simple interventions such as reminders sent to parents about the importance of reading to their children can have large effects: US parents of children in subsidized preschool programs considerably increased the time they spent reading to their children. Yet, further research needs to be done to improve our understanding of the role of early educational interventions for the cognitive development of (disadvantaged) children in the long run. Moreover, studies about children's wellbeing need to go beyond assessing health status and cognitive abilities and also consider emotional and behavioral health and the development of positive personality traits (Akee et al., 2015).

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Appendix

Figure A1: Distribution of the verbal score, by test type

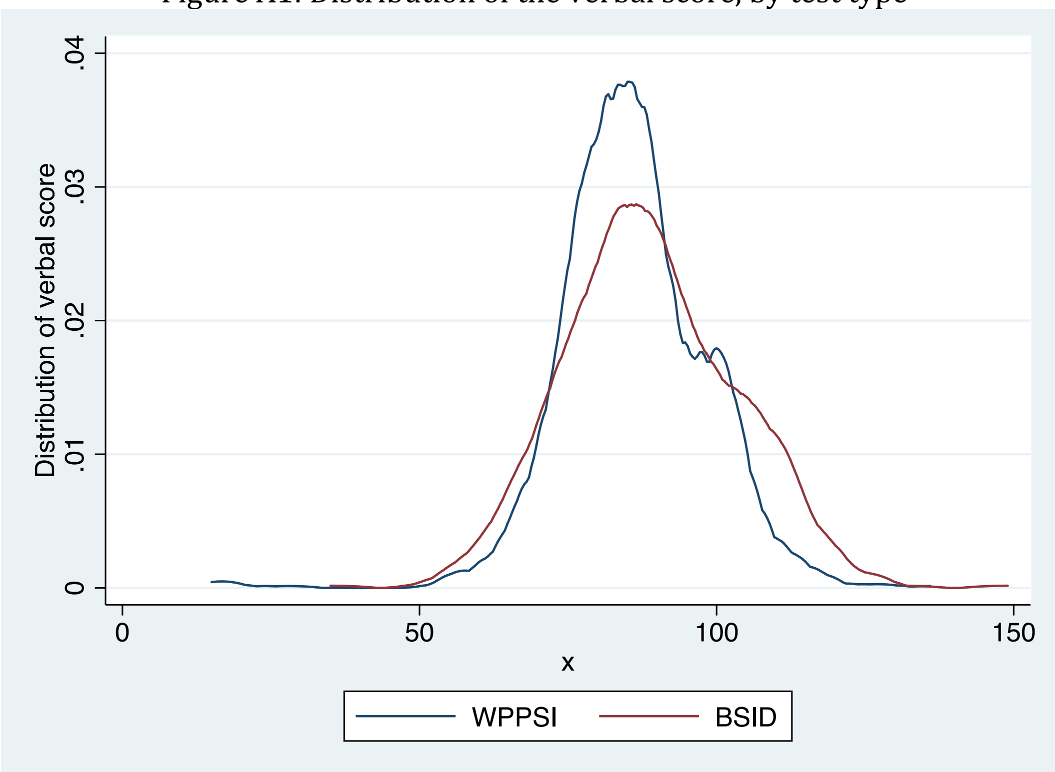

Table A1: WPPSI components by sub-test

Main Composite Scores	Subtests: WPPSI Young	Subtests: WPPSI Old
Verbal	Receptive vocabulary Information	Information Vocabulary Word reasoning
Performance	Block design Object assembly	Block design Matrix reasoning Picture concepts

Source: Wechsler (2002)

Table A2: Summary statistics for the verbal score and the covariates

	Total		Round 1		Round 2	
Variable	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Cognitive development scores						
Verbal score	86.991	13.224	89.165	14.395	84.817	11.545
WPPSI full score for all children taking the test	85.933	12.278				
BSID verbal score in round 1			88.719	14.483		
WPPSI verbal score in round 1			90.571	14.061		
Child took BSID in round 1	0.380	0.485	0.759	0.428		
Home learning environment	32.231	7.547	30.421	6.902	34.042	7.731
Health indicators						
WAZ	-1.250	1.331	-1.023	1.304	-1.478	1.319
HAZ	-1.600	1.442	-1.506	1.592	-1.694	1.268
Normal hemoglobin level	0.637	0.481	0.689	0.463	0.586	0.493
High lead level	0.216	0.412	0.314	0.464	0.119	0.324
Child characteristics						
Child is male	0.570	0.495	0.570	0.495	0.570	0.495
Age in months	36.386	19.254	21.650	12.419	51.123	12.361
Guardian and household characteristics						
Guardian years of education	7.819	9.478	8.562	3.316	7.076	12.949
Female guardian	0.893	0.309	0.899	0.301	0.888	0.316
Household size	6.114	2.341	5.729	2.260	6.499	2.358
Ratio of dependents of 0-14 years	1.235	0.802	1.170	0.708	1.299	0.881
Ratio of dependents of 65+ years	0.059	0.229	0.040	0.157	0.078	0.281
Per capita household income	1,036.597	1,242.240	987.980	1,264.733	1,085.214	1,218.219

Note: The total number of observations is 1,530 corresponding to 765 observations per round. In the first round of data collection, 581 children took the Bayley cognitive test and the remaining 184 took the Wechsler test.

Table A3: Regression results for the verbal score

Outcome: Verbal development score	OLS	FE Basic model	FE with family composition
Home learning environment	0.600***	0.526***	0.534***
	(0.047)	(0.062)	(0.062)
Health indicators			
WAZ	0.502*	0.682*	0.637*
	(0.274)	(0.385)	(0.380)
HAZ	0.066	-0.227	-0.215
	(0.237)	(0.349)	(0.347)
Normal hemoglobin level	1.451**	1.745*	1.730*
	(0.627)	(0.892)	(0.891)
High lead level	-0.155	0.566	0.704
	(0.745)	(1.008)	(0.999)
Child characteristics			
Age in months	-0.413***	-0.390***	-0.402***
	(0.031)	(0.103)	(0.103)
Child took BSID in round 1	-9.300***	-7.094***	-7.118***
	(1.200)	(1.256)	(1.242)
Guardian and household characteristics			
Guardian years of education	-0.002	-0.053	-0.047
	(0.030)	(0.039)	(0.041)
Female guardian	0.041	-1.124	-1.282
	(0.924)	(1.594)	(1.584)
Household size	-0.358***	0.779	0.628
	(0.131)	(0.480)	(0.476)
Ratio of dependents of 0-14 years			0.569
			(0.685)
Ratio of dependents of 65+ years			5.274***
			(2.030)
Per capita household income	-0.000	0.000	0.001
	(0.000)	(0.001)	(0.001)
Child FE	No	Yes	Yes
Round FE	Yes	Yes	Yes
Within variance explained by covariates		0.186	0.193
Variance explained by child FE		0.395	0.398
Hausman FE vs RE test (p-value)		0.014	

Note: Across specifications the total number of observations is 1,530 corresponding to a total number of 765 children. Standard errors are clustered at the child level. ***/**/* indicates significance at the 1/5/10 percent level, respectively.

Table A4: Comparison of means between the estimation sample and attrited observations for the verbal score

	Estimation sample			Attrited observations			Difference in means test (p-value)
	Sample size	Mean	Std. Dev.	Sample size	Mean	Std. Dev.	
Child is male	1,530	0.570	0.495	756	0.556	0.497	0.514
Age in months	1,530	36.386	19.254	756	36.422	18.981	0.967
Guardian and household characteristics							
Guardian years of education	1,530	7.819	9.478	752	7.999	7.488	0.649
Female guardian	1,530	0.893	0.309	754	0.903	0.296	0.473
Household size	1,530	6.114	2.341	751	6.085	2.213	0.776
Ratio of dependents of 0-14 years	1,530	1.235	0.802	738	1.361	0.938	0.001***
Ratio of dependents of 65+ years	1,530	0.059	0.229	738	0.049	0.186	0.319
Per capita household income	1,530	1,036.597	1,242.240	741	1,016.702	1,029.944	0.706

Note: Comparison of means for covariates that are available in both sub-samples. ***/**/* indicates significance at the 1/5/10 percent level, respectively.