The production function of cognitive skills: nutrition, parental inputs and caste test gaps

Florencia López Bóo *
Inter-American Development Bank/IZA
1300 New York Av., NW (E0605), Washington DC, 20577

February 26, 2010

Abstract

This paper explores the determinants of children's cognitive outcomes using novel panel data from two cohorts of children in India. As in Todd and Wolpin's study (2007), I do not find evidence supporting restrictive models that assume test scores depend only on contemporaneous inputs. In models where past inputs are not observed or imperfectly measured, past nutritional status and/or past test scores turn out to be a good proxy-indicator of this variable, which is evidence for the 'sufficiency' assumption. I allow for the endogeneity of nutrition using an instrumental variable approach and find that a 1 standard deviation increase in height-for-age z-scores at the age of 1 leads to cognitive test scores that are about a quarter of a standard deviation higher at age 5. I also study the behaviour of home inputs and find that parents seem to 'reinforce' children for early favourable outcomes rather than 'compensate' them for adverse scores; and they do so more in lower caste families and particularly with boys.
JEL Classification Codes: J13, J15, J24
Keywords: cognitive outcomes,nutrition, children and test score gaps.

*email: florencial@iadb.org. The author wishes to thank M.N.Asadullah for very helpful discussions. The paper also benefited from excellent comments received from G. Kingdon and also from P.Glewwe, S.Dercon, P.Engle, J.Gignoux, J. Rud, M. Smitz and the Research Department of the IDB seminar participants. This research was funded by Young Lives, a longterm international research project investigating the changing nature of childhood poverty. Young Lives is core-funded by the UK Department for International Development (DFID) for the benefit of developing countries. Sub-studies are funded by IDRC (in Ethiopia), UNICEF (in India), the Bernard van Leer Foundation (in India and Peru) and Irish Aid (in Vietnam). The views expressed here are those of the authors. They are not necessarily those of the Young Lives Project, the University of Oxford, DFID or any other funders, neither those of the Inter-American Development Bank or their boards of directors.

1 Introduction and Literature Review

Much importance has been given lately to the examination of the relevance of cognitive skills, mainly because of its power to explain school and professional success (Heckman 1995). It is also known that cognitive abilities are formed relatively early in life and become less malleable as children age. At least two factors contribute to shaping children's ability: genetic endowment, and the home environment. Many studies highlight the importance of genetic inheritance (Teasdale and Owen 1983, Wilson 1983). Nevertheless, other studies (from studying twins) also show that even if about 50 per cent of the variance in child development is due to genetic factors, a child's genetic expression is very much influenced by his environmental inputs, particularly at younger ages. [1]

These findings have motivated a large amount of research on the disparities between socio-economic groups that can arise from a lack of early childhood investments or interventions (Carneiro, Cunha, and Heckman 2003, Heckman 2005, Cunha and Heckman 2007). Using secondary survey data for developed countries, researchers have addressed many issues related to early parental investments or public policy interventions and the cumulative nature of cognitive abilities in a variety of ways (Lally, Mangione, and Honig 1988, Murnane, Willett, and Levy 1995, Garces, Thomas, and Currie 2002, DeCicca 2007, Temple and Reynolds 2007). Despite these recent advances in the literature, rarely does research on early childhood use developing country data.

Nonetheless, the motivation for research on developing countries comes from the fact that limited or inappropriate nutrition and stimulation early in life, and sometimes discrimination in the intra-household allocation of resources (Grantham-McGregor et al 2007, Kingdon 2002, 2005), problems so intrinsic to the developing world, might prevent the development and catch up of disadvantaged children. The existing evidence in less developed countries (Engle et al. 2007, Grantham-McGregor et al 2007, Walker et al. 2007) has shown the positive effects of pre-school, cash transfers and nutritional status on school performance or cognitive outcomes of mostly school-aged children.[2] [3]

[1] For instance, Scarr and Weinberg (1983) found that young siblings (black/interracial adoptees) were intellectually similar to their natural brothers.

[2] For instance, see Berlinski et al (2008) for evidence on positive effects of pre-school attendance on third grade grades scores in Argentina. On the positive effects of cash transfer programmes on cognitive outcomes, especially language, in pre-school aged children see: for rural Nicaragua, Macours et al (2008), Gertler and Fernald (2004) for the Mexican *Oportunidades* as well as Paxson and Schady (2007) for the Ecuadorian *Bono de Desarrollo Humano* sample.

[3] Investments in nutrition have been shown to be one of the most important predictors of later cognitive development in developing countries, while there is not much evidence on morbidity effects other than malaria (via iron status) and possibly diarrhoea. For a review see Grantham-McGregor et al (2007). For experimental studies from a longitudinal study in Guatemala see Hoddinot et al (2008), Behrman et al (2008) and Maluccio et al

Particularly, a survey study by Schady (2006) finds that differences in test performance by socio-economic status (SES) persist as children age. Divisions by SES in India are defined according to whether a household belongs to a certain caste. Gang et al (2008) find that differences in educational attainment explain about 25 per cent of the poverty gap between both the Scheduled Caste and Schedule Tribe and non-Scheduled-Hindu households (for further information on castes, see Appendix 2). For that reason, in the recent past, the government of India has introduced a range of policy interventions targeting social groups like Scheduled Castes (SCs) and Scheduled Tribes (STs). Some evidence shows that these interventions have been successful (Jenkins and Barr 2006), particularly for STs. And indeed, most of the existing studies on determinants of school participation and attainment in India today acknowledge socio-religious differences in the population (Dreze and Kingdon 2001, Kingdon 2002, Dostie and Jayaraman 2006). In these studies, low attendance and completion of lower castes (LCs) is explained by a range of factors including rural infrastructure, conditions in the local village economy, the functioning and size of the relevant labour market, household credit-constraints, sex discrimination, and the poor quality and inadequate supply of schools. However, none investigates the effects of early childhood conditions on the process of skill formation by caste.

The objective of this analysis is therefore to fill an important gap in the literature by investigating determinants of a child's development of cognitive skills over two phases of childhood: pre-school and school ages. To the best of my knowledge, this is the first study using panel data to assess: firstly, the causal relation between nutrition and cognition at pre-school age in India; secondly, the *direct* impact of parenting practices and the *indirect* impact of better parenting that improves a child's overall nutrition status on current and later receptive vocabulary test scores and general intelligence test scores; as well as the behaviour of parental investments (i.e., compensating/reinforcing early outcomes) with respect to past performance and nutritional status;[4] and thirdly, whether there are socio-economic gradients/gaps that emerge already in childhood and how they are mediated by early family investments. For that, I exploit the novel and rich measures of parental inputs, anthropometrics and cognitive outcomes provided in the Young Lives longitudinal data (YL hereafter).[5] This data consists of two cohorts of children (the 'younger' and the 'older') surveyed over two rounds four years apart (Round 1 in 2002 and Round 2 in 2006).

(2009). More related to this paper is the experimental work of Grantham-McGregor and co-authors (1991, 1997) who provides evidence that parenting interventions may be more effective than health interventions in Jamaica.

[4] Parental reinforcing practices are defined as those practices that use nutrition or other inputs to reinforce differences in children's outcomes (i.e., more gifted children will receive more inputs as a reward), while compensating practices are those that attempt to equalise learning outcomes.

[5] See www.younglives.org.uk

Furthermore, the methodology used here allows me to go beyond previous empirical studies. Todd and Wolpin (2007) model cognitive skills as a function of the child's innate genetic ability and the cumulative effect of present and past home and school investments. I therefore examine determinants of cognitive outcomes in different specifications for all ages in both cohorts. This structural production function analysis makes considerable progress in sorting out the causal relationship between nutrition, home inputs and cognitive outcomes. The challenge in estimating this relationship is that of other inputs being missing, a problem solved by the rich YL data.

However, yet another problem is that unobserved child, parents or household-specific factors may affect both nutrition (home inputs) and cognitive outcomes, which may lead to a correlation even though no causation exists. This research will then take into account the endogeneity of nutritional status, as measured by height-for-age (HAZ hereafter) explicitly, while also exploring the determinants of parental inputs. I argue that since one important indicator of child malnutrition (low birth-weight) and one of its major determinants (mother's height) are established well before the age at which the tests were given, the identification problem is ameliorated.[6]

I find strong evidence that better cognitive outcomes are related to a better nutritional status in early childhood, evidence which survives numerous robustness checks, even including the history of past parental inputs in the cumulative specification. Past test scores are an important determinant of current test scores, which supports the *self-productivity* effects present in Cunha and Heckman (2008). Using a specification that incorporates these features, I analyse test score gaps between lower castes (LCs) and upper castes (UCs) and find that equalising nutrition at the average levels of UC children would close the caste test score gap by about 18.7 per cent, while by equalising home inputs at the average levels of UC children would close the caste test score gap by 9.5 per cent. Furthermore, when analysing the behaviour of parental inputs over time, estimates show a 'compensating' attitude for adverse early nutritional endowments and a 'reinforcing' attitude for favourable past test scores, particularly in LC households and with boys. This paper proceeds as follows. The second section describes the methodology for modeling the production function and considers its empirical application and challenges. The third section gives details on the data and variables used to represent outcomes, home inputs and controls, while the fourth section presents descriptive statistics. The fifth section shows estimates of the cognitive skills production function. Parental investment demand functions are presented and I use the estimated production function to evaluate caste disparities in test scores. The last section concludes.

[6] These two instrumental variables (IVs) are interpreted as "conditions" which are free of influences by the home environment at birth. If the results are robust, it would imply that there is a pathway from the IV, through HAZ, to cognitive skills that is separate from family-specific influences.

2 Methodology

In this section I outline the basic theoretical model that provides the basis for the empirical estimation. The empirical approach and its associated challenges are also discussed below.

2.1 Theoretical framework

The main interest of this paper lies in investigating the various *direct* and *indirect* determinants of current cognitive skill formation, with a particular focus on the effects of a child's past cognitive skill levels, nutritional status and parental investment. For that reason, I discuss both a cognitive skills and nutrition production function, as well as parental inputs demand functions.

2.1.1 Cognitive achievement production function

I follow Todd and Wolpin (2003, 2007) and Cunha and Heckman (2008) in writing the skill level of child i at age t [7] as a function of current parental investment, and other contemporaneous variables including child, caregiver and household current characteristics.

$$\theta_{it} \; = f(I_{it}, H_{it}, X_{it}, \mu_{it}, \epsilon_{it}) \tag{1}$$

where i denotes individuals, θ_{it} denotes a child's cognitive skill level for age t with $t \, \epsilon \, (0...\mathrm{T})$, I_{it} denotes parental investment at age t, H_{it} denotes nutritional status at age t and X_{it} denotes a vector of characteristics of child i, his caregiver and his home, μ_{it} is the *expression* of the child's endowed mental capacity ('ability') and ϵ_{it} is an error term that includes the effect of the history of unobserved inputs and measurement error, hence ϵ_{it} is expected to be serially correlated.

In order to capture the (unobserved) genetic endowment with which a child is born, Todd and Wolpin propose to take first differences of a linear specification of equation (1); that is, substracting θ_{it-1} from both sides where first differences of skill levels are interpreted as value-added, which gives:

$$\theta_{it} \; = f(\theta_{it-1}, I_{it}, H_{it}, X_{it}, \mu_{i0}, \epsilon_{it}) \tag{2}$$

This value-added specification relates a cognitive skills outcome measure to contemporaneous family input measures (inputs applied between the baseline measure and a current measure) and a lagged (baseline) skills measure, nutrition and other co-variates.[8] In the next sub-section, I show

[7] I will omit the fact that child i is in household j for notation convenience.

[8] Because ϵ_{it} is expected to be serially correlated, I should have taken first differences, however I am not able to do so because I would have needed: i) longer panel data and ii) two measurements per child on the same dependent variable (i.e., I have PPVT at age 12 and Ravens at age 8).

two versions of equation (2): the contemporaneous one (as specified here for generality), and the cumulative one that includes I_{it-1} and H_{it-1}.

The key assumption of this model is that the baseline skills and nutrition measures are taken to be a sufficient statistic for input histories, and in the versions of the model that do not incorporate endowments, the lagged test score and nutritional status are also taken as sufficient statistics for endowed mental capacity. When a baseline skills measure is not available (i.e., for the Younger Cohort) lagged nutritional status alone will be taken as a sufficient statistic. Evidence based on the value-added specification is generally regarded as more convincing than that based on a contemporaneous specification (Summers and Wolfe 1977, Hanushek 1996).

2.1.2 Nutritional status production function

Nutritional status (H_{it}) is the product of genetics and a household production process, where time and market goods are inputs used to produce child health. [9] Given wages and prices, parents maximise their utility subject to the full income constraint that includes both time and income. The production of child health is then consistent with theoretical notions that relate H_{it} to a process of interaction of child, family and non-family factors (including health-inputs and the child's genetic endowment). Therefore, the nutrition production function is:

$$H_{it} = f(IH_{it}, X_{it}, E_i) \tag{3}$$

where H_{it} is the measure of child nutrition, IH_{it} represents lagged health and nutrition-related inputs used to produce H_{it}, such as parents' time spent with child and other inputs, including the efficiency of parents (or parental quality), X_{it} are family (i.e. health-related home inputs) and non-family (i.e. public health services, access to water and sanitation in the community) influences and E_i is the child genetic endowment.

2.1.3 Parental inputs demand function

The input demands are specified as functions of exogenous child and family characteristics, home characteristics, lagged test scores (or lagged nutrition outcomes, depending on specification), a children heterogeneity term (μ_i), and an independently distributed shock (ϵ_{it}), as follows:

$$I_{it} = f(\theta_{it-1}, H_{it}, X_{it}, \mu_i, \epsilon_{it}) \tag{4}$$

$$IH_{it} = f(H_{it-1}, X_{it}, \mu_i, \epsilon_{it}) \tag{5}$$

[9] T his discussion is based on health (H) production functions, where the household production function approach assumes that parents increase their utility if children are in good health, which implies the existence of a demand function for child nutritional status.

where I_{it} and IH_{it} represent inputs used to produce skills, θ_{it}, and nutrition, H_{it}, respectively. These input demand functions do have standard interpretations as demand functions even when there are unmeasured inputs in the above equation, provided the prices of these inputs and other factors affecting their demands are controlled for in the vector X_{it}. [10] The coefficient on either θ_{it-1} or H_{it-1} reflects 'self-productivity' effects.

2.2 Empirical strategy for estimation of the production function of cognitive skills

In order to facilitate the modeling of various outcomes and inputs, I have explicitly made assumptions about the timing of corresponding measurements. For instance, nutrition and cognitive outcomes are revealed at the end of period $t-1$ (or the very start of t), while decisions about nutrition and other inputs are made at the beginning of t. In addition, i.i.d. random shocks μ_{it} (for the child) and ϵ_{it} (for the household/family) are assumed to be realised at the start of time t. Now, assuming linearity in the production function (2), the estimation equations will take the following forms:

The contemporaneous specification This specification relates test scores in the tth. period to data only on contemporaneous inputs:

$$\theta_{it} \ = \alpha I_{it} + \gamma H_{it} + \delta X_{it} + \beta' \mu_{i0} + \epsilon_{it} \tag{6}$$

Here, test scores are being produced with current nutrition, H_{it}, both observed and unobserved contemporaneous inputs, I_{it}, and endowments, μ_{i0} ,[11] plus other child, family and community factors, X_{it}, and ϵ_{it} is a random error term.

The cumulative specification This specification expands the contemporaneous one by including observable lagged inputs and nutrition (I_{it-1} and H_{it-1}) and test scores, θ_{it-1}, as in the equation below:

$$\theta_{it} \ = \alpha_1 I_{it} + \alpha_2 I_{it-1} + \gamma_1 H_{it} + \gamma_2 H_{it-1} + \delta X_{it} + \zeta \theta_{it-1} + \beta_t \mu_{i0} + \epsilon_{it} \tag{7}$$

Ideally, data will be available to measure complete historical *cumulative* nutrition inputs. However, the simpler alternative is to use the child's nutritional status as a summary statistic for the nutritional history up to that age. Thus, within a multi-period framework, H_{it-1} refers to the end of the previous period and is a sufficient statistic for all previous inputs and prices. Therefore, equations (6) and (7) are the ones to be finally estimated.

[10] It is then assumed that parents are attempting to maximise a well-defined expected utility function subject to a per-period budget constraint with the optimal choice of inputs being obtained from conditional demand functions.

[11] The fact that the coefficient on unobserved genetic endowments is a constant independent of age, β', yields equation (6).

2.2.1 Endogeneity of Child Nutritional Status and Home Inputs

A common problem in the production function approach to studying child outcomes relates to endogeneity of particular regressors, such as nutrition or home inputs. Particularly, since parental taste for child quality and a child's genetic ability are unobserved, Ordinary Least Squares (OLS) estimations of the nutrition-learning nexus, as well as the parental investment-learning nexus are likely to be biased. The main challenge of estimating either equation (6) or (7) arises from the possibility that at least one of the following problems appears.

First, if there are unobserved parental preferences in ϵ_{it} that may be correlated with the inputs, $E(H_{it}$ (for example, parents with a strong preference for child investments will provide their children with inputs that improve both child nutritional status and cognitive skills. This could thus lead to an *omitted variable bias* and upwardly bias the estimates of the coefficient on nutrition or home inputs.

Second, correlation between inputs and the residual can emerge if nutrition (and/or home inputs) are functions of, among other things, child learning efficiency or "endowment", μ_i, which represents factors, such as ability and motivation, that are out of parents' control but are influenced by home environment as well as by genetics (Rosenzweig and Wolpin 1988). This leads to *simultaneity bias* in a production function, which could go in either direction. Two mechanisms for this has been suggested in the literature: (a) contemporaneous inputs (and/or nutrition) and unobserved mental capacity might not be orthogonal if parents use nutrition or other inputs to reinforce differences in children's learning ability or "endowment". However, even if that orthogonality condition were satisfied, OLS estimation would still be biased due to a second problem (b) baseline skills, θ_{it-1} and/or nutrition status, H_{it-1} must be correlated with endowed mental capacity, μ_{i0}.

Finding a valid, strong instrument to deal with endogeneity due to *omitted variable bias* and *simultaneity bias* is challenging. Instead, the standard approach has been to follow a two-prong strategy, whereby as many household as child controls, together with IV, are jointly implemented (Glewwe, Jacoby, and King 2001, Alderman, Hoddinott, and Kinsey 2006). The strategy through which the above issues are accounted for is described the paragraphs below:

Controlling for family/community/school characteristics, lagged scores and lagged inputs In order to solve the problem of endogeneity due to the *omitted variable bias* problem, a class of estimators used to 'control' for permanent unobservable factors makes use of variation across observations within which the unobservable factor is assumed to be fixed. One such "fixed effect" estimator prominent in the literature uses variation that occurs within families/children, but unfortunately I do not have the data at hand. The inclusion of as many family and child controls as possible, added to past test scores and inputs, allows for a solution to this problem. I therefore standardise the test scores available for the Older Cohort children at two different ages, allowing this specification to be performed in a modified version of the cumulative or valued-added (VA) specification, as in equation (7), where 'modified' stands for a VA specification that includes past test scores and past inputs and nutrition in the right-hand-side (RHS). Given the standardization, I can only measure whether a child has moved up in the *relative* ranking. Probably most importantly, quality of parental investment is unobserved (Waldfogel 2006), but some of the observed variables will hopefully capture such unobservables (e.g., breastfeeding, antenatal care, immunisation, etc).

IV To solve endogeneity due to the *simultaneity bias* problem I attempt: firstly, to use a lagged measure of nutritional status (HAZ) as a regressor; [12] and secondly, to instrument past nutritional status with birth-weight for the Younger Cohort. Birth-weight is a measure of innate endowments and it should not be contaminated by parental investments on the basis of revealed innate ability. In that sense, this instrument deals with endogeneity due to condition (a), although it leaves (b) unresolved. Unfortunately birth-weight is unavailable for the Older Cohort, therefore, and on a similar basis, I use mothers' height, mothers' age and the interaction of the two for the Older Cohort (Thomas, Strauss, and Henriques 1990). See also section 5.2 for alternative, but weaker, IVs used.

Parental investment driven by observable differences between siblings The rich set of controls included for family and non-family characteristics will deal with factors that are common across families. Yet parents could favour one sibling based on observable features. To take into account two of the most recognised possibilities, I will include birth order and gender (i.e., a child can be favoured because he is the first born or because of his gender).

Taking all elements together, the proposed strategy takes care of both *omitted variable bias* and *simultaneity bias* problems, particularly in the preferred specification where nutritional status and/or past scores are assumed a sufficient statistic for the history of observed and unobserved inputs. In brief, the regression technique employed for both cohorts will be IV-OLS and will have the following steps depending on the cohort being analysed:

- Younger: OLS estimation of equation (3)

[12] This could be itself endogenous in that it proxies for unobserved innate endowments. However the IV estimation plus other robustness tests using data on birth-weight will solve this problem

- Older: OLS estimation of parental investment functions (4) and (5)
- Older: OLS-IV estimation of VA function (7)
- All: OLS-IV estimation of equations (6) and (7)

3 Data

3.1 General description

I use data from the Indian survey of the Young Lives (YL) project. Young Lives is an innovative longitudinal research project investigating the changing nature of childhood poverty in four countries (Ethiopia, India , Peru and Vietnam) over 15 years. At present I am able to use information from two rounds of data collection from Andhra Pradesh, India. [13]

In Round 1, 2,000 children aged around 1 (the 'Younger Cohort') and 1,000 children aged around 8 (the 'Older Cohort') were surveyed in 2002. Following up, Round 2 tracked the same children and surveyed them in 2006 at age 5 and 12, respectively. The attrition rate was only 0.9 per cent. which is very low for a study of this size. In terms of the representativeness, despite a few biases (see Kumra (2008) in a note comparing the YL survey to DHS), it is shown that the YL sample in Andhra Pradesh covers the diversity of children in the country.[14] This stratified cluster sample is both region and caste representative. And the estimation used in this study incorporates the YL survey design by using regions as the stratification variable and the sentinel sites as the clustering variable.

3.2 Description of key variables

Table 1 shows key variables of interest. A brief introduction to the main

[13] Andhra Pradesh (AP) state is divided into 23 administrative districts, which are each subdivided into a number of mandals or sentinel sites, dependent upon the size of the district. There are 1,125 mandals and around 27,000 villages in AP. Generally, there are between 20 and 40 villages in a mandal, although in tribal mandals there can be as many as 200 villages. Villages are normally composed of a main village site with a small number (two to five) of associated hamlets. Tribal villages tend to have a large number of dispersed hamlets. AP has three distinct agro-climatic regions: Coastal Andhra, Rayalaseema and Telangana. The sampling scheme adopted for YL was designed to identify interregional variations with the following priorities: (1) a uniform distribution of sample districts across the three regions to ensure full representation; (2) the selection of one poor and one non-poor district from each region; and (3) when selecting poor districts and mandals, consideration was given to issues which might impact upon childhood poverty, including the presence or non-presence of the AP District Poverty Initiative Programme (APDPIP).

[14] However, Andhra Pradesh has more educated women and lower rates of malnutrition than the worst off states in the north.

Table 1: Structure of key variables in YL data

	Cognitive Skills Test (⋆)	Nutritional status/Health	Inputs: Parental (●)/School (○)
Age 1 Younger cohort Round 1	-	HAZ	● Freq. child sees father (if daily/weekly=1) ● Caregiver's depression ● Whether birth in hospital or attended by trained person ● Level of antenatal care (= 1 if medium/high,= 0 if none/low ● Whether child had a BCG, measles and polio immunisation ● Whether mother had iron folate tablets ● Whether child had recommended 6 or + months breastfeedin
Age 5 Younger cohort Round 2	Peabody Picture Vocabulary Cognitive Development Assessment	HAZ	● Freq. child sees father (if daily/weekly=1) ● Whether father is dead ● Whether child had complete immunisation ○ Whether child attended pre-school ○ Whether pre-school public/private/religious or NGO
Age 8 Older cohort Round 1	Ravens Coloured Progressive Matrices Reading level Writing level	HAZ/BMI/TDS	● Freq. child sees father (if daily or weekly =1) ● Whether father is dead ● Whether child works ● Whether child performs household chores ● Whether child reads as a hobby ●Whether child does not have a hobby at all ○ Years ago child made to start formal schooling ○ Years of school
Age 12 Older cohort Round 2	Peabody Picture Vocabulary Reading level Writing level Numeracy level (*)	HAZ/BMI	● Freq.child sees father (if daily or weekly =1) ● Whether father is dead ● Whether child works ● Hours child play in a typical day (=1 if $\geq$ 2 hs/day) ●Whether child had complete immunisation ○ Years of school ○ Whether school is public or private

(*) I focus on the Ravens scores and the PPVT, while the writing, reading and CDA tests serve as robustness tests. Note 1: HAZ stands for height-for-age z-score and is based on 2006 WHO standards. Note 2: Other measures used as robustness test of HAZ as proxy of health status for both cohorts in Round 1 are: (i) has child been sick in last two weeks (yes/no); (ii) how is health of child compared to others (same, better, worse); (iii) has the child had any long term health problem (yes/no); (iv) in the last three years has the child had a serious illness or injury where you really thought they might die (yes/no). For the 1-year-olds, I also built a child health index based on the sum of positive answers to the following episodes: loose or watery stools, blood, fever, cough, rapid breathing, vomit, serious loss of appetite, convulsions, unconsciousness and lethargy. Results using any of these are consistent with those that use HAZ.

variables is given below.

3.2.1 Cognitive skills

I focus on two tests that measure different aspects of cognitive abilities: the Ravens test measures non-verbal reasoning while the Peabody Picture Vocabulary Test (PPVT hereafter) measures vocabulary knowledge. I also use a measure of quantitative ability (the Cognitive Development Assessment, CDA) as a robustness test. See Appendix 1 for more details on these tests.

A concern might be related to the effect of the language in which the tests were provided. Actually, the questionnaires and the manuals for the field supervisors were translated into Telugu.[15] But still, it is hard to assume that people responding to a vocabulary test in different languages could be compared. For this reason, the analysis for the PPVT is restricted to the children who answered the PPVT test in Telugu (95 per cent of the 12 year-olds in the Older Cohort and 90 per cent of the 5 year-olds in the Younger Cohort). [16]

3.2.2 Nutritional status

The rationale for the use of HAZ is that deficit in the height-for-age measure corresponds to the inability to reach the genetic potential in terms of height. This is viewed as a longer term measure of deprivation than weight-for-height, which is more sensitive to short-term or seasonal variations in food availability. Height is also said to have a strong relationship with mental function and mortality.

HAZ is therefore used as an input in the production function of skills; however, for children aged 1, and given the lack of cognitive outcomes, I only estimate a nutritional status production function as in equation (3).

For the 8-years-old, I also include in the production function the Total Difficulties Score (TDS), a measure of mental health. Finally, for both the 8 and the 12-year-old, I also use as a robustness test the absolute value and z-score of the Body Mass Index (BMI).

3.2.3 Home input measures

Grantham-McGregor et al (1991) find that both food supplementation and home stimulation were important, while Powell (2004) demonstrates how to intervene on stimulation for improved development. The findings show that parenting interventions may sometimes be more effective than health

[15] About 85 per cent of the Andhra Pradesh population identifies Telegu as its mother tongue (the second most commonly spoken language in India), another 7.5 per cent speak Urdu, and about 3 per cent speak Hindi. In the YL data, only 4.2 per cent of children speak a minority language.

[16] Throughout the paper I obtained consistent results using this sample as compared to (i) the full sample or (ii) the full sample with inclusion of a statistical control for whether the respondent spoke the language of the test since birth.

interventions in improving cognitive outcomes, underscoring the importance of assessing an index of parental home inputs.

I calculate the total home input score (or index) in two ways: firstly, the "raw" index is an equal-weight summation of responses (modified so each has a [0,1] domain) of the individual items shown in Table 1 for a given cohort, age and round.

Secondly, the index is calculated as the output of factor analysis of the correlation matrix of all parental investment indicators also shown in Table 1. Given the strong assumption associated with an equal-weight summation, the score presented in the rest of the paper is the factor score, whose calculation and tabulation is briefly described in Appendix 3.[17] Some of the items can be directly linked to cognitive skills in the sense that they are related to learning-specific skills. For example, primary caregivers are asked whether the child does household chores (which can be taken as "time not-spent on learning"). Other items are not too easily tied to cognitive development, but may be thought of as investment in child well being and creating an environment conducive to learning. [18]

Lastly, for those 5, 8 and 12-year-olds I also use school indicators, which could be interpreted as home and/or school input. For instance, if children go to (better) private schools, this could be taken as a higher "home input", as parents made the decision of the type of school they wished their child to attend.

3.2.4 Control variables

Control variables refer to the caregiver, father and home characteristics as well as geographical dummies. Caregiver characteristics are age, caste and education. Father's education and home characteritics such as the wealth index (Filmer and Pritchett 1998) and household size, are also included. The wealth index has three components: housing quality, consumer durables and services. Geographical dummies included are: Coastal Andhra and Rayalaseema (with Telangana being the base category) and whether the household is located in a urban or rural area.

[17] Eigen values of the correlation matrix and the factor loadings are available upon request.

[18] Cunha and Heckman (2008) argue that these types of index can be arbitrary and instead of creating an index of parental inputs, they estimate an index that best predicts latent skill dynamics. See Helmers and Patnam (2009) for an application to the case of India.

4 Descriptive statistics

The means and SDs of all relevant variables are presented in Tables 2 and 3 below. The first column presents results for the full sample, the second column for LCs (composed of SCs and STs), the third column for Backward Classes (or BC) [19] and the fourth column for UCs. The last two columns show p-values for the difference of means between LCs and BCs, and UCs and LCs, respectively (the latter being the most relevant comparison for this paper).

Overall, and based on the analysis of these two tables and the existing literature, I find that Andhra Pradesh has achieved progress on children development indicators since the mid-1990s. However, even though LCs and BCs have become wealthier and increasingly urban in both cohorts, significant differences remain based on sector (rural versus urban), caste and region.

In Table 2 it is shown that in both the PPVT and CDA-Q tests, there is no significant difference betwen BCs and SC/STs, while UCs do significantly better (25 per cent in PPVT and 7.4 per cent in CDA-Q) than LCs and BCs. The level of stuntedness increased over time for both the UCs and the LCs, but remained about 20 percentage points lower for UCs (at 16 per cent when they were 1 year-old, and at at 22 per cent four years later). In Table 3 one can observe that the UC 8 year olds have 11 per cent higher Ravens scores than LC, while 12-year-olds belonging to an UC score also 11 per cent higher in the PPVT. Disparities are also significant in nutrition outcomes at age 8: 32 per cent of LCs and 35 per cent of BCs are stunted, as opposed to 25 per cent of UCs (there is actually an increasing gap in stunting between LC and UC children in Round 2). In terms of the mental health index, TDS at age 8 presents 58 per cent of LCs children as 'normal' and 40 per cent of UCs as such.

In both cohorts, there is a remarkable increase in urbanisation rates among LCs, who went from about 10 per cent to around 40 per cent. Households are larger in UCs and in BCs; while LCs are poorer than BCs, who themselves are poorer than UCs (as per the wealth index). Over time, all castes and cohorts are becoming richer, but as inequality increases, UCs end up benefiting more from growth.

In the Younger Cohort, UC mothers have two and three times more years of schooling than BCs and LCs, respectively, averaging a total of 6.4 years of education completed. For fathers, the differences, though significant, are

[19] There is no consensus in the literature on whether to explicitly treat this category as a separate social group. Jenkins and Barr (2006) and Dreze and Kingdon (2001) consider SC and ST as separate from Backward Castes on the grounds that completion rates are much lower than for other groups. I have therefore separated out this group and explicitly controlled for BC membership in the results section. I have also further split the lower caste group between SC and ST.

Table 2: Younger Cohort: Means and t-tests, main variables by caste

	All	LC	BC	UC	t test (p-val)	
					LC-BC	UC-LC
Cognitive scores						
PPVT	42.03	41.11	38.52	51.48	0.11	0.00
CDA Q	9.52	9.23	9.43	10.13	0.15	0.00
Peabody PVT (z-sc)	0.01	-0.02	-0.10	0.30	0.11	0.00
CDA Q (z-sc)	0.00	-0.11	-0.03	0.23	0.15	0.00
Child						
% PPVT in Telugu	0.90	0.89	0.96	0.77	0.00	0.00
Coastal Andhra	0.35	0.35	0.36	0.32	0.67	0.37
Rayalaseema	0.30	0.28	0.28	0.39	0.87	0.00
Telangana	0.35	0.37	0.36	0.29	0.78	0.01
ST	0.18	0.59				
SC	0.13	0.41				
BC	0.48					
UC	0.21					
R2 pre-school	0.87	0.82	0.89	0.88	0.00	0.02
R2 private	0.28	0.13	0.27	0.51	0.00	0.00
Child nutrition						
R1 HAZ	-1.29	-1.52	-1.30	-0.93	0.01	0.00
R1 stunted	0.27	0.36	0.26	0.16	0.00	0.00
Birth-weight	2,766	2,691	2,750	2,847	0.22	0.00
R2 HAZ	-1.61	-1.75	-1.66	-1.29	0.11	0.00
R2 stunted	0.34	0.39	0.36	0.22	0.36	0.00
Home						
R2 urban	0.35	0.37	0.28	0.45	0.00	0.01
R2 hhsize	5.52	5.29	5.60	5.67	0.01	0.00
R2 wealth index	0.36	0.28	0.36	0.48	0.00	0.00
CG and DAD						
R1 CG age	23.76	23.57	23.56	24.52	0.98	0.00
R1 CG edu	3.25	1.90	2.89	6.06	0.00	0.00
R1 DAD edu	5.34	4.95	5.24	6.12	0.00	0.00
R1 CG depress	0.30	0.41	0.26	0.23	0.00	0.00
R2 CG edu	3.50	2.07	3.14	6.41	0.00	0.00
R2 DAD edu	5.37	4.21	5.00	7.91	0.00	0.00
Parental investment						
R1 antecare index	1.94	1.70	1.99	2.18	0.00	0.00
R1 birth hospital	0.59	0.43	0.62	0.77	0.00	0.00
R1 leftnobreast	0.30	0.15	0.31	0.50	0.01	0.00
R1 seedad	0.98	0.97	0.98	0.98	0.25	0.73
R1 deaddad	0.00	0.00	0.00	0.00	0.66	0.81
R1 complete imm	0.72	0.73	0.69	0.78	0.15	0.06
R1 irontabs	0.95	0.92	0.95	0.97	0.01	0.00
R2 seedad	0.94	0.94	0.95	0.93	0.62	0.38
R2 deaddad	0.02	0.02	0.02	0.02	0.58	0.74
R2 complete imm	0.93	0.91	0.95	0.94	0.01	0.04

Source: Young Lives-India, Younger Cohort. Prefix R1 (R2) means the value comes from Round 1 (Round 2). Means are taken on children observed in both rounds (N=1950). LCs are: Scheduled Caste (SC) and Scheduled Tribes (ST). Other Backward Classes (BC) include Muslims, while UCs are those classified in the YL data as Other Castes. HAZ=height-for-age z-score and CG=caregiver. Mothers' height is not available for the Younger Cohort and therefore not reported in this table.

Table 3: Older cohort: Means and t-tests, main variables by caste

	All	LC	BC	UC	t test (p-val)	
					LC-BC	UC-LC
Cognitive scores						
PPVT	135.42	130.83	134.06	145.37	0.28	0.00
Ravens	22.98	22.20	22.77	24.59	0.14	0.00
Peabody PVT (z-sc)	0.00	-0.11	-0.03	0.25	0.28	0.00
Ravens (z-sc)	0.00	-0.15	-0.04	0.31	0.14	0.00
R1 Writing	2.34	2.28	2.28	2.55	0.99	0.00
R1 Reading	3.08	2.87	3.06	3.43	0.01	0.00
Child						
% PPVT in Telugu	0.95	0.99	0.97	0.86	0.08	0.00
Coastal Andhra	0.34	0.36	0.37	0.26	0.75	0.03
Rayalaseema	0.31	0.27	0.27	0.43	0.99	0.00
Telangana	0.35	0.37	0.36	0.31	0.76	0.16
ST	0.20	0.67				
SC	0.10	0.33				
BC	0.49					
UC	0.21					
R1 years in school	2.46	2.40	2.46	2.56	0.34	0.05
R2 years in school	6.52	6.32	6.57	6.69	0.01	0.00
R2 public	0.63	0.71	0.64	0.47	0.04	0.00
Child health						
R1 HAZ	-1.52	-1.61	-1.55	-1.34	0.36	0.00
R1 TDS	0.57	0.58	0.63	0.40	0.38	0.01
Home						
R2 urban	0.34	0.36	0.30	0.43	0.07	0.12
R2 hhsize	5.20	5.21	5.16	5.27	0.67	0.74
R2 wealth index	0.37	0.29	0.37	0.47	0.00	0.00
CG and DAD						
R1 CG age	31.04	31.35	30.73	31.33	0.19	0.96
R1 CG edu	2.34	1.19	2.07	4.65	0.00	0.00
R1 DAD edu	5.08	4.44	5.01	6.19	0.00	0.00
R2 CG edu	2.61	1.31	2.38	5.06	0.00	0.00
R2 DAD edu	4.50	2.88	4.19	7.60	0.00	0.00
Mothers height	150.3	149.7	150.2	151.5	0.55	0.04
Parental investment						
R1 chldwork	0.06	0.10	0.05	0.03	0.02	0.00
R1 seedad	0.94	0.91	0.96	0.93	0.01	0.33
R1 deaddad	0.03	0.04	0.02	0.04	0.07	0.87
R1 child HH chores	0.33	0.45	0.29	0.26	0.00	0.00
R1reads as hobby	0.15	0.11	0.16	0.18	0.03	0.03
R1no hobby	0.03	0.07	0.02	0.00	0.00	0.00
R2 deaddad	0.08	0.10	0.07	0.09	0.09	0.65
R2 chldwork	0.21	0.25	0.22	0.09	0.33	0.00
R2 immunization	0.39	0.38	0.35	0.51	0.33	0.00
R2 hours play	3.78	4.04	3.74	3.47	0.06	0.01

Source: Young Lives-India, Older Cohort. See notes for Table 2. Means are taken on children observed in both rounds (N=994).

not so ample: UC fathers have about one to three years more education than BC fathers, and two to four years more than LC.

The caregiver's depression index, a strong psycho-social well-being risk factor, shows that 23 per cent of UC and 41 per cent of LC caregivers report being depressed. [20] Another important predictor of children's success is parental nutrition, and a good proxy at hand in YL data is caregiver's height: as expected, LC mothers are 2 cm. shorter than UC mothers. [21]

In terms of the inputs variables for the Younger Cohort it is shown in Table 2 that more UCs than LCs: i) were born in a hospital or with a medically trained person, ii) had been given iron folate tablets/syrup during the antenatal visits, iii) had better level of antenatal care (LCs having a low-medium level of care), iv) had timely immunisation, v) go to pre-school, and vi) go to private and NGO-run pre-schools.

However, there is no caste difference in the frequency at which children see their fathers. Moreover, UCs children are left one month more without breastfeeding from the benchmark of six mandatory months recommended.

Now turning to the inputs variables for the Older Cohort, it is shown in Table 3 that more UCs than LCs: i) had timely immunisation (51 percent of UCs as opposed to 38 per cent of LCs), ii) go to school (and engage much less in paid work), iii) go to private school and iv) report reading as a hobby. Meanwhile, at age 12, UCs play less hours/day than LCs. All reported differences are statistically significant.

Overall, disparities between castes are particularly important in cognitive tests, nutrition outcomes, wealth, caregivers' and fathers' level of education and some parental inputs. In general, I find a significant advantage amongst UCs in inputs and background, suggesting that these can be one source of the disparities found in cognitive and nutritional outcomes.

5 Results

5.1 Younger cohort: The cumulative nutrition production function at age 1 and caste effects

A better environment and child health *per se* are known to be associated with skill accumulation (Grantham-McGregor et al. 2007). However, nutritional status is also, at least partially, the outcome of received home inputs and household characteristics. Therefore, prior to studying the nutrition-cognitive skills nexus, I estimate the cumulative version of equation (3). Another relevant question will be to assess whether the inclusion of the

[20] YL uses the Self-responding Questionnaire (SRQ20) to determine and measure the psycho-social well-being of the caregiver. They count the number of "Yes" responses to the 20 relevant questions (i.e. headache, poor appetite, bad sleep, etc).

[21] 98.5 per cent of the caregivers are the biological mothers in this sample.

Table 4: The production function of nutrition, cumulative specification for 1-year-olds

	OLS, dependent variable: HAZ	
	(1)	(2)
Age of child (months)	-0.10***	-0.10***
	(0.01)	(0.01)
male dummy	-0.13**	-0.13**
	(0.06)	(0.06)
firstborn	0.74	0.74
	(0.76)	(0.76)
lastborn	-0.04	-0.03
	(0.07)	(0.07)
Coastal Andhra	0.04	0.05
	(0.08)	(0.08)
Rayalaseema	0.79***	0.78***
	(0.08)	(0.08)
Urban dummy	-0.07	-0.08
	(0.10)	(0.10)
Household size	-0.02*	-0.03*
	(0.01)	(0.01)
Wealth index	0.85***	0.75***
	(0.23)	(0.23)
Age of caregiver	0.02**	0.02**
	(0.01)	(0.01)
Caregiver's education level	0.02**	0.02**
	(0.01)	(0.01)
Father's education level	0.02	0.02
	(0.02)	(0.02)
Home Input 1 yr old (factors-scored)	0.09**	0.08*
	(0.04)	(0.04)
Scheduled Caste		-0.09
		(0.09)
Scheduled Tribe		-0.11
		(0.11)
Upper Castes		0.09
		(0.09)
Constant	-1.05***	-0.97***
	(0.25)	(0.25)
Observations	1769	1769
R-squared	0.15	0.15
F-Test: caregiver characteristics & parental inputs	4.60	3.99
Prob > F	0.00	0.00
F-Test: caregiver characteristics & parental inputs & caste		3.14
Prob > F		0.00
Chi-square	24.40	20.05
Prob > F	0.00	0.00

Note 1: Standard errors in parentheses. Note 2: *** p<0.01, ** p<0.05, * p<0.1 Note 3: Home Input 1 yr old is an index (based on factor analysis) of parental investment as described in the text. Note 4: Telangana Region is the base category.

different castes dummies still influences early child nutritional status after controlling for a rich set of co-variates.

Table 4 shows that age of child in months is negatively correlated with height-for-age z score, capturing the fact that the WHO HAZ score is not age-normed. Girls appear better nourished than boys, a finding probably related to a well-known fact in the demographic literature on male-to-female ratios in child mortality over the first year of life.[22]

Children living in Rayalaseema seem to be healthier than children living in Telangana, which is not a surprise as this is one of the state's most impoverished areas after suffering from agrarian crisis for several consecutive years. As expected, HAZ is negatively correlated with household size, while it is positively correlated with wealth. However, birth order and urban status do not have any significant effects on HAZ.

Caregiver characteristics are significant: for each additional year of caregiver's education, HAZ scores are on average 2 per cent of 1 SD higher. On the other hand, the father's level of education does not seem to have any influence on the production function of nutrition, probably due to the young age of children. Lastly, for each 'point' increase in the home input score, HAZ scores are on average 9 per cent of 1 SD higher, a larger effect than the education of the caregiver. In the second column, after the inclusion of the LC (negative and non-significant) and UC (positive and non-significant) dummies, all coefficients stay significant and similar in magnitude, except for the wealth index. This result is consistent with the fact that the covariates included capture most of the differences between castes.

5.2 Younger cohort: The cumulative production function of skills at age 5, nutrition and home inputs effects

Different versions of equation (7) are estimated below: the OLS and the IV version are shown in Tables 5 and 6, respectively. In Table 5, column (1) shows the baseline specifications in which level of education of the caregiver and father; and whether the child is ST have significant effects. Of most interest is the coefficient on past height-for-age on the PPVT, which implies that raising HAZ by 1 SD will increase child test score by 11 per cent of 1 SD, a bigger effect than any of the parental background effects. In column (2), after the inclusion of the (non-significant) pre-school dummy, all variables remain unaltered, suggesting that pre-school attendance is not a particularly important determinant of language abilities. In column (3), I also include the current home input index, which, even if positive, turns out to be insignificant. Home inputs at age 1 (in the factors scored version but also each individual variable of the index) were included in an older

[22] One study using DHS's surveys finds that girls are almost 10 percentage points less likely to die in the first year of life than boys (Baird et al 2007). Also, the World Health Organization (2006) estimates that the male-to-female ratio in neonatal and early neonatal mortality in developing countries is 1.3.

version of the paper, but are not reported after finding that past nutrition is a better indicator of past inputs than the lagged home input index or any of its individual components. [23]

In column (4), the significant coefficient on past nutrition suggests that PPVT scores depend not only on contemporaneous but also lagged HAZ, providing evidence against the contemporaneous specification. Lastly, column (5) replicates column (4), but now the dependent variable is the CDA. Results are qualitatively similar, except for change of sign (from positive to negative) in the coefficient on Coastal Andhra and the importance of pre-school attendance.

In terms of the performance of different castes, the effect of belonging to an ST household on the PPVT remains consistently positive and significant throughout, except for the CDA for 5 year olds and (as will be shown in the next sub-section) the Ravens, suggesting that there is some feature of the PPVT at which STs fare significantly better than BCs, even after netting out differences in child, caregiver, home and parental characteristics. On the other hand, in the CDA specification, SCs are performing significantly worse, as expected.

Table 6 replicates the specifications in columns (3) and (4) from Table 5 for a truncated sample for the PPVT and the CDA, respectively. Here past (or current) nutrition is instrumented with birth-weight in columns (3), (4), (7) and (8).

In sum, results in columns (3) and (7) show that OLS estimates in columns (1) and (5) underestimate the IV estimate effect of past HAZ on PPVT and CDA z-scores: for each SD increase in past HAZ, PPVT scores are on average 24 per cent of 1 SD higher, while CDA scores are 46 per cent of 1 SD higher. OLS in columns (2) and (6) also underestimates the effects of current nutrition, but only in the case of CDA scores. The 1st stage (Cragg-Donald) F-statistics are over 35 for both cognitive tests in the case of specifications with past nutrition, and over 10 in the specifications that include current nutrition instead. These F-statistics seem to show that birth-weight works via past nutrition better than via current nutrition. Overall, this downward bias of the OLS estimate of HAZ (i.e., OLS estimate smaller than the IV) seems to indicate that nutrition is more relevant than what is shown by OLS. Actually parents, after observing low birth-weight, might be attempting to compensate by adjusting their inputs upwards and as a result equalising tests outcomes with those of healthier children. This will push down the coefficient on HAZ.

[23] Moreover, including past inputs in the specification in column (3) - with or without past health - shows that past home inputs matter in the production function of cognitive skills, which allows for the rejection of the contemporaneous specification. However, when past health is included along with the past home inputs index, these are not jointly significant and the coefficient on past health is larger.

Table 5: The production function of skills, cumulative specification for 5-year-olds (OLS)

	Peabody Picture Vocabulary Test z scores				CDA test z scores
	(1)	(2)	(3)	(4)	(5)
Age of child (months)	0.04***	0.04***	0.04***	0.04***	0.05***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
male dummy	0.05	0.05	0.05	0.05	-0.02
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
firstborn	0.19	0.19	0.20	0.23	0.44
	(0.51)	(0.51)	(0.51)	(0.51)	(0.53)
lastborn	0.00	0.00	0.00	0.01	-0.04
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
Coastal Andhra	0.14**	0.14**	0.14**	0.13**	-0.24***
	(0.06)	(0.06)	(0.06)	(0.06)	(0.05)
Rayalaseema	0.08	0.08	0.08	0.09	-0.03
	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
Urban	0.38***	0.38***	0.38***	0.38***	0.26***
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
Household size	-0.01	-0.01	-0.01	-0.01	0.00
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Wealth index	0.36**	0.36**	0.35**	0.29*	-0.09
	(0.16)	(0.16)	(0.16)	(0.16)	(0.16)
Caregiver's education level	0.04***	0.04***	0.04***	0.04***	0.03***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Father's education level	0.02***	0.02***	0.02***	0.02***	0.03***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Past HAZ	0.11***	0.11***	0.11***	0.09***	0.06***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Scheduled Caste	-0.04	-0.04	-0.04	-0.05	-0.11*
	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
Scheduled Tribe	0.51***	0.51***	0.50***	0.49***	0.06
	(0.08)	(0.08)	(0.08)	(0.08)	(0.07)
Upper Castes	0.02	0.02	0.02	0.01	0.00
	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
Pre-school dummy		-0.03	-0.03	-0.03	0.16**
		(0.07)	(0.07)	(0.07)	(0.06)
Home inputs score - 5yr olds			0.09	0.09	0.08
			(0.09)	(0.09)	(0.09)
Current HAZ				0.07***	0.10***
				(0.03)	(0.03)
Constant	-3.11***	-3.08***	-3.00***	-2.81***	-2.94***
	(0.38)	(0.38)	(0.39)	(0.40)	(0.39)
Observations	1612	1612	1612	1612	1841
R-squared	0.28	0.28	0.28	0.28	0.16
Test joint signif: parental background & nutrition	34.35	34.37	34.47	30.69	19.04
Prob > F	0.00	0.00	0.00	0.00	0.00
Test joint signif:parental background & inputs	-	-	36.10	34.63	18.88
Prob > F	-	-	0.00	0.00	0.00

Note 1: Standard errors in parentheses. Note 2: *** p<0.01, ** p<0.05, * p<0.1 Note 3: The Home Input score index is composed by the variables of care as described in the text. Note 4: Columns (3) and (4) are the Cumulative (or VA) specification.

Table 6: The production function of skills, cumulative specification for 5-year-olds (instrumenting HAZ with birth weight)

	Peabody Picture Vocabulary test z scores				CDA test z score			
	OLS		IV		OLS		IV	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Caregiver's education level	0.05***	0.05***	0.05***	0.05***	0.03***	0.03***	0.03***	0.04***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Father's education level	0.02*	0.02*	0.02	0.01	0.02**	0.02**	0.01	0.00
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Past HAZ	0.15***		0.24*		0.11***		0.46***	
	(0.03)		(0.14)		(0.03)		(0.14)	
Current HAZ		0.19***		0.54		0.14***		0.34***
		(0.04)		(0.34)		(0.04)		(0.14)
Home inputs 5yr (factors-sc)	0.18	0.16	0.17	0.14	0.16	0.15	0.15	0.10
	(0.15)	(0.15)	(0.15)	(0.16)	(0.14)	(0.14)	(0.15)	(0.18)
Scheduled Caste	-0.03	-0.09	0.00	-0.10	-0.06	-0.10	0.07	-0.11
	(0.11)	(0.11)	(0.12)	(0.12)	(0.11)	(0.11)	(0.13)	(0.14)
Scheduled Tribe	0.58***	0.53***	0.60***	0.53***	0.11	0.08	0.21	0.11
	(0.15)	(0.15)	(0.16)	(0.16)	(0.14)	(0.14)	(0.16)	(0.18)
Upper Castes	0.11	0.10	0.11	0.08	-0.03	-0.04	-0.02	-0.11
	(0.09)	(0.09)	(0.09)	(0.10)	(0.08)	(0.08)	(0.09)	(0.11)
Pre-school dummy	0.21*	0.18	0.23*	0.20	0.20*	0.22**	0.09	0.14
	0.12	0.12	0.12	0.12	0.10	0.10	0.12	0.14
Constant	-4.34***	-3.96***	-4.44***	-3.55***	-3.64***	-3.34***	-3.97***	-2.23**
	(0.64)	(0.64)	(0.67)	(0.79)	(0.58)	(0.58)	(0.65)	(0.89)
Observations	713	713	713	713	795	795	795	795
R-squared	0.31	0.31	0.30	0.23	0.18	0.18	0.02	0.02
CD Wald F-stat	-	-	33.37	10.64	-	-	37.61	14.12

Note 1: Standard errors in parentheses. Note 2: *** p<0.01, ** p<0.05, * p<0.1 Note 3: The Home Input score index is composed of the variables of care described in the text. Note 4: The C-D Wald F stat is the Cragg-Donald Wald F-statistic of weak identification. Note 5: Child, region, pre-school and home controls are always included.

The implication of these results is important: the effect of past HAZ on PPVT and CDA scores is independent of the source of variation of HAZ, whether it is due to the variation in birth-weight, home, household, region, home inputs or caregivers' characteristics, including caste. Given the consistency of the effect of past HAZ in Table 5 and the OLS estimations in Table 6 (0.10 on PPVT and 0.06 on CDA), and the IV results in Table 6 (0.24 on PPVT and 0.46 on CDA), one can conclude that the nutrition-cognition nexus is important in Andhra Pradesh, while the home inputs-cognition relation is far less important.

5.3 Older Cohort: The contemporanous specification of the production function of skills at age 8, nutrition and home inputs effects

For the 8-year-olds I estimate equation (6). Results in Table 7 show that current health (both physical and mental) influence the contemporaneous scores of the Ravens test in the expected direction and in a similar fashion. [24] For each SD increase in the TDS, Ravens scores are on average 7.5 per cent of 1 SD lower, and for an SD increase in current HAZ, Ravens scores range from an average of 6 to 8 per cent of 1 SD higher, which indicates that physical and mental health seem equally important at age 8.

It is interesting to note that even the effect of caregiver's education is less important than nutrition (coefficient=.05), and that neither father's education nor any of the caste dummies are a significant determinant of the Ravens scores, even if they have the expected sign (positive for UCs and negative for SC/STs). Most importantly, after controlling for the number of years spent in school in column (2) and successively adding a control for the current home input score index in column (3), the coefficients on height-for-age and mental health remain unaltered.

Nevertheless, schooling does matter and its coefficient doubles that of either HAZ or TDS. Moreover, given the non-significant coefficient on the home inputs score, one could think that HAZ is already capturing the effects of (past and current) parental investment on test scores, supporting again the sufficiency assumption. [25] Lastly, the low R-squared value seems to indicate that there is still an important portion of the variance that cannot be captured with the data at hand, probably the most important being unobserved child endowments.

[24] However, it is only the mental health index (and not HAZ) that has an influence on writing and reading levels (these results are available upon request).

[25] F-tests show the joint significance of caregiver characteristics with (respectively): nutrition, school and home inputs variables.

Table 7: The production function of skills, cumulative specification for 8-year-olds

	Ravens test score (OLS)		
	bsline	bsline + school	bsline + school + HI
	(1)	(2)	(3)
Caregiver's education level	0.05***	0.05***	0.05***
	(0.01)	(0.01)	(0.01)
Father's education level	0.03	0.03	0.03
	(0.02)	(0.02)	(0.02)
HAZ	0.08**	0.07**	0.06**
	(0.03)	(0.03)	(0.03)
TDS	-0.07*	-0.08*	-0.08*
	(0.04)	(0.04)	(0.04)
Scheduled Tribe	-0.02	-0.03	-0.04
	(0.08)	(0.08)	(0.08)
Scheduled Caste	-0.05	-0.02	-0.03
	(0.12)	(0.12)	(0.12)
Upper Caste	0.13	0.12	0.12
	(0.09)	(0.09)	(0.09)
years school		0.15***	0.14***
		(0.04)	(0.04)
Home Input 8 yr old (factors-scored)			0.03
			(0.04)
Constant	-2.68***	-2.42***	-2.34***
	(0.84)	(0.83)	(0.84)
Observations	912	912	908
R-squared	0.13	0.14	0.14
F-Test: parental background & nutrition	6.86	6.30	6.25
Prob > F	0.00	0.00	0.00
Test joint signif:parental background & school	-	8.16	8.26
Prob > F	-	0.00	0.00
Test joint signif:parental background & inputs	-	-	7.76
Prob > F	-	-	0.00

Note 1: Standard errors in parentheses. Note 2: *** p<0.01, ** p<0.05, * p<0.1 . Note 3: The Home Input score index is composed by the variables described in the text Note 4: The highest the Total Diff Score, the worst the mental health. Note 5: Child, region, pre-school and home controls are always included.

5.4 Older cohort: The value added specification of the production function of skills at age 12

Table 8 shows the cumulative specification, estimated by OLS in columns (1) to (4) and by IV methods in columns (5) to (7). The model that allows for child-specific unobserved endowments nests the cumulative model with endowments that are orthogonal to included inputs. Under the null that endowments are uncorrelated with inputs, the OLS estimator applied to equation (6) is consistent, but under the alternative it is inconsistent.

This baseline equation is estimated in column (1) while column (2) adds castes dummies and home inputs at age 12. Equation (7) is estimated in column (3) and (4) where past home inputs and Ravens score are included to test the contemporanous versus the cumulative "value added" specification. In column (5), I replicate column (4) but now instrument past nutrition with mother's height and the interaction of mother's height and age. While variation in mothers' height is found in any healthy population, it also reflects heterogeneity in these women's early childhood disease susceptibility. To the extent that disease susceptibility is genetically inherited, mother's height should be correlated with the nutrition determined component of child height. [26]

Past HAZ is significant at the 86 per cent level in columns (5) and (7), while the IV version in column (6) shows that increasing 1 SD past HAZ will increase average PPVT scores by around 32 per cent of 1 SD at the 90 per cent level of significance, which shows a downward bias of OLS, and then an indication of compensating behaviour when poor health outcomes are observed, consistent with results from the Younger Cohort.[27]

Both parents' education variables affect cognitive skills in the expected direction. However, caregiver's education is more important than father's education in the OLS specifications, a trend that reverses in the IV specification (columns 5 and 7). This makes sense as the IVs are related to mothers' endowments and may be taking out the effect of education. When comparing these sets of results with those of the previously analysed age groups, the most salient feature is that caregiver's educational level matters much more at age 5 and 8 (coefficient=0.04 to 0.05) than at age 12 (coefficient=0.02), which is understandable since outside factors start to influence cognitive skills as the child grows older. Moreover, the coefficient on father's education is very stable with a coefficient of around 0.02 for all ages. Meanwhile, the Scheduled Tribes positive coefficient shows an advantage with respect to

[26] Subsequent columns are robustness tests of the specification in column (5). Reading and writing scores are added in column (6) and the full sample is used in column (7) (i.e., it includes children whose first language is not Telugu, that is, they speak Hindi, Urdu, Oria, Kannada, Marati, Tamil, or local dialects).

[27] I have also included past BMI scores and BMI z-scores (not reported) as a measure of health for 8 year-olds and the results are remarkable similar.

Table 8: The production function of skills, cumulative specification for 12-year-olds (instrumenting past HAZ with mothers' height and age)

	Peabody Picture Vocabulary test z scores						
	OLS				IV		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Caregiver's education level	0.03***	0.03**	0.03**	0.02*	0.01	0.00	0.00
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Father's education level	0.02*	0.01	0.01	0.01	0.02*	0.02	0.01*
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
past HAZ	0.00	-0.01	-0.01	-0.01	0.26	0.32*	0.36
	(0.03)	(0.03)	(0.03)	(0.03)	(0.21)	(0.16)	(0.22)
Scheduled Caste		-0.04	-0.04	-0.04	-0.03	0.00	-0.03
		(0.08)	(0.08)	(0.08)	(0.08)	(0.09)	(0.08)
Scheduled Tribe		0.23**	0.23**	0.25**	0.30*	0.31*	0.27*
		(0.11)	(0.11)	(0.11)	(0.12)	(0.13)	(0.12)
Upper Caste		-0.02	-0.02	-0.03	-0.07	-0.06	0.00
		(0.08)	(0.08)	(0.08)	(0.09)	(0.10)	(0.09)
Home inputs score, age 12		0.21***	0.21***	0.20***	0.19***	0.16***	0.18***
		(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.02)
Home inputs score, age 8			0.01	0.01			
			(0.03)	(0.03)			
Ravens (z-score), age 8				0.13***	0.11***	0.08**	0.10***
				(0.03)	(0.03)	(0.04)	(0.04)
Writing level child, age 8						0.11**	
						(0.05)	
Reading level child, age 8						0.10**	
						(0.04)	
Constant	-0.71	-0.97	-0.94	-0.43	-0.24	-0.55	-0.48
	(1.10)	(1.05)	(1.06)	(1.05)	(1.11)	(1.20)	(1.10)
Observations	863	863	863	863	863	832	961
R-squared	0.19	0.27	0.27	0.28	0.21	0.18	0.13
F-Test: parental background & nutrition	4.22	3.15	3.15	3.15	-	-	-
F-Test: parental background & inputs	-	19.25	16.49	16.49	-	-	-
F-Test: Ravens-age 8 & nutrition	-	-	-	8.22	-	-	-
F-Test: Ravens-age 8 & inputs	-	-	-	52.81	-	-	-
Sargan stat	-	-	-	-	0.00	0.063	0.01
C-D Wald F stat	-	-	-	-	9.22	7.29	8.67

Note 1: Standard errors in parentheses. Note 2: *** p<0.01, ** p<0.05, * p<0.1 Note 3: The Home Input score index is composed of variables as described in the text. Note 4: C-D Wald F stat is the Cragg-Donald Wald F-statistic of weak identification. Note 5: Child, region, school and home controls are always included

the base category (BCs), which is also true for the IV version. Furthermore, there is a positive, consistent and significant association of home inputs at age 12 and PPVT scores, even if that relationship is not clear for past home inputs in column (3). A similar specification test can be used to examine the support for the value added model. The key assumption of this model is that the lagged test score is a sufficient statistic for historical inputs and, when the model that does not incorporate endowments, it is also taken to be a sufficient statistic for endowments. To test the first assumption, I have included lagged input measures in the value-added specification, which should have no additional explanatory power under the sufficiency assumption. The estimate in column (4) shows that for test scores presented here, the lagged home input measure at age 8 is not statistically significantly different from zero. I interpret these results as evidence for the 'sufficiency' assumption.

Moreover, given the concern that the Ravens scores can be affected by school attendance, I have added reading and writing levels in column (6). The Ravens at age 8 has a consistent positive effect on the PPVT at age 12: increasing 1 SD in the Ravens test will significantly increase average PPVT scores by somewhere between 8 and 13 per cent of 1 SD. This is clear evidence against a contemporaneous specification. As there are no lagged input measures (say, home inputs at age 7 and less), I do not know whether their omission could be engendering an overstatement of the impact of a unit increase in Ravens score. Writing and reading levels have a quantitatively similar (positive and significant) impact on PPVT scores. Using the full sample in column (7) does not change the results, confirming that home inputs, lagged test scores (at a lower level of significance) and father's education are the main determinants of performance in the PPVT test, with other factors like caste and nutrition having, unexpectedly, little effect. The fact that caregiver's education is not significant should be taken with caution given that one of the IV's is related to mother's endowment. [28]

A logical extension of this analysis is to consider effects by the sign (positive if z-score above mean or negative if z-score below mean) and the magnitude of the Ravens scores. I do so by showing a non-parametric regression of the z score of PPVT (in standard units) as a function of the z score of the Ravens test. [29]

Results in Figure 1 are based on colum (6) in Table 8 and show the analyisis for: i) full sample, ii) by gender and iii) by caste. The figure shows

[28] The relative importance of overall family background is confirmed by the F-test, which always returns a highly significant F-statistic.

[29] Specifically, I regress the PPVT on a set of co-variates and predict the residual from this regression. I also regress Ravens on the standard covariates and predict the residuals from this regression. Finally, locally weighted least squares are used to depict the relation between the residual from the PPVT z-score and the residual from the Ravens z-score regression. This approach is closely related to the two-stage procedure. For presentational purposes, the figure is trimmed at the 1st and 99th percentiles of Ravens deviation.

an upward sloping relationship between PPVT and Ravens scores for the whole sample. It is shown that a one log-unit increase in the Ravens would increase the PPVT by 20 per cent.

I next extend this analysis to consider differences by gender, again focusing on the sign and magnitude of the Ravens. The figure suggests that boys and girls' positive PPVTs are similarly related with positive Ravens. On the other hand, a negative Ravens at the very bottom of the distribution (below -2) implies a much larger (negative) effect in girls later scores, a result that is consistent with the fact that families might protect boys more than girls at the bottom of the distribution of the Ravens. Put differently, this suggests that gender-differentiated household responses to very bad test scores play an important role in determining later cognitive skills, and very likely later success in life.

More striking is the analysis by caste, which suggests that UCs positive Ravens are related with much larger later scores than LCs. Also, overall, negative Ravens for LCs are correlated with much larger (negative) PPVTs, again suggesting important differential dynamic effects by SES.

5.5 Older cohort: parental investment demand functions

The estimations above allow input choices to be correlated with a child's fixed endowment but assumes that, conditional on endowment, input choices do not respond to earlier test score realisations. It is plausible, however, that parents might adjust their input choices in response to their child's earlier test score outcomes, as suggested by results in Figure 1. To analyse this in more detail, a demand function for parental investment is estimated below. Results in Table 9 seem to indicate that, conditional on endowments, exogeneity of the input choices (i.e., one of the identifying assumptions) is rejected for the Ravens and the reading test score measures at a 1 per cent level. These results provide evidence that input choices are correlated with endowments and with the unobserved components of achievement realisations (conditional on endowments), as expressed by past cognitive skills.

The positive estimated coefficients of Ravens, writing and reading scores on the home input measures – columns (1) and (2)–, school decisions – column (3)–, immunisation –column (4)– and the play time –column (5)– show that parents seem to be 'reinforcing' good earlier outcomes such as test scores rather than 'compensating' for poor earlier outcomes. This is the opposite of the result found for nutrition outcomes in both cohorts with the IV approach.

Lastly, Table 10 replicates Table 9 by gender and by caste. It is interesting that the 'reinforcing' behaviour found earlier seems to be driven by boys and LC children for the Ravens and the writing tests, but not for the reading test. The finding on boys is consistent with the idea of pro-male discrimination in the intra-household allocation of resources. However, this result gives additional information, as discrimination not only happens after observing the sex of the child, but it happens again after observing some objective measure of achievement (interacted with gender). The reading of the results for the LCs is more complex. Probably, parents under extreme conditions of poverty will have to spread their resources more stringently, and therefore end up allocating more resources to the more able children, rather than the neediest in the household.

Table 9: Parental investment functions, 12-year-olds

	Home inputs		Schooling	Immunisation	Play time
	(1)	(2)	(3)	(4)	(5)
Ravens (z score), age 8	0.17***	0.12**	0.11***	0.02	0.14**
	(0.05)	(0.05)	(0.04)	(0.01)	(0.07)
Writing level, age 8		0.11	0.11**	0.00	-0.07
		(0.07)	(0.06)	(0.02)	(0.10)
Reading level, age 8		0.26***	0.28***	-0.04***	0.04
		(0.05)	(0.04)	(0.01)	(0.07)
Age of child (months)	0.03***	0.03***	0.04***	0.00	0.00
	(0.01)	(0.01)	(0.01)	(0.00)	(0.01)
male dummy	-0.09	-0.14*	-0.11	0.04	0.63***
	(0.09)	(0.09)	(0.07)	(0.02)	(0.12)
firstborn	0.38***	0.37***	0.25**	0.05	-0.16
	(0.12)	(0.12)	(0.10)	(0.03)	(0.17)
lastborn	0.06	0.11	0.08	0.01	0.20
	(0.11)	(0.11)	(0.09)	(0.03)	(0.15)
Constant	0.53	0.22	-0.51	0.41	4.14*
	(1.61)	(1.57)	(1.32)	(0.45)	(2.24)
Observations	926	926	926	935	935
Core controls	yes	yes	yes	yes	yes
R-squared	0.31	0.35	0.25	0.42	0.24

Note 1: Standard errors in parentheses. Note 2: *** p<0.01, ** p<0.05, * p<0.1. Note 3: Core controls refer to child, caregiver, home and region.

Table 10: Parental investment functions- Home Inputs -, 12-year-olds, by gender and caste

	Female	Male	SC/ST	Upper Caste
	(1)	(2)	(3)	(4)
Ravens (z score), age 8	0.05	**0.18*** **	**0.12** **	0.13
	(0.07)	(0.07)	(0.05)	(0.08)
Writing level, age 8	0.04	**0.21** **	**0.20** **	-0.22
	(0.09)	(0.10)	(0.08)	(0.13)
Reading level, age 8	**0.19*** **	**0.32*** **	**0.24*** **	**0.24** **
	(0.07)	(0.07)	(0.06)	(0.10)
Age of child (months)	0.04***	0.01	0.03**	0.02
	(0.02)	(0.01)	(0.01)	(0.02)
male dummy	0.00	0.00	-0.02	-0.55***
	(0.00)	(0.00)	(0.10)	(0.16)
firstborn	0.36**	0.41**	0.27*	0.71***
	(0.17)	(0.17)	(0.14)	(0.21)
lastborn	0.11	0.11	0.07	0.22
	(0.15)	(0.15)	(0.13)	(0.19)
Constant	-1.57	1.82	0.03	2.18
	(2.30)	(2.15)	(1.86)	(2.71)
Observations	474	452	726	200
Core controls	yes	yes	yes	yes
R-squared	0.36	0.37	0.34	0.43

Note 1: Standard errors in parentheses. Note 2: *** p<0.01, ** p<0.05, * p<0.1. Note 3: Core controls refer to child, caregiver, home and region.

Table 11: PPVT caste gap closed by home inputs and by nutrition: VA specification with lags for Older Cohort

	Actual caste gap	Predicted caste gap	Closed by nutrition	Closed by home
All	11.1	10.5	1.96	1.00
			(18.7%)	(9.5%)
Boys	11.8	9.2	1.98	0.50
			(21.5%)	(5.4%)
Girls	10.3	11.9	2.08	3.18
			(17.5%)	(26.7%)

Note 1: The percentage of the gap closed is in parentheses. Note 2: The predicted caste gap in the Ravens for 8-year-olds is 12.1 per cent.

5.6 Caste test score gaps

Using the production function estimates from column (6) in Table 8 (preferred IV specification), I examine the extent to which differences in HAZ and inputs can account for caste disparities in test scores. I examine the fit of the model by comparing the actual values of test score gaps by age to the gap predicted under the model by caste group. The estimated model captures key features of the data, such as the magnitude of the gap for each of the groups and the slight decrease in the gap over time (see Table 11). Because the estimated production function coefficients do not vary by caste, [30] the decreasing gap in the predicted test scores arises from caste differences in various inputs. Lastly, I examine how the predicted test score gaps vary if I set the levels of HAZ and home inputs for LC at the average levels observed for UC children (i.e., what the gap would have been if LC children received the UC average levels of home inputs). It is shown in Table 11 that if HAZ is equalised at the average UC level, then the PPVT test score gap would be reduced by 18.7, while if home inputs are equalised at the average UC level, then the PPVT test score gap would be reduced by 9.5 per cent. Again, it is interesting to note that the gap between UC and LC for boys is closed by more than one fifth when equalising HAZ and only 5 per cent when equalising the home inputs index. For girls, one fourth of the gap would be closed by home inputs and 17.5 per cent by leveling nutritional status.

[30] Except for the STs coefficient in some specifications, but not in the preferred one.

6 Conclusions and further research

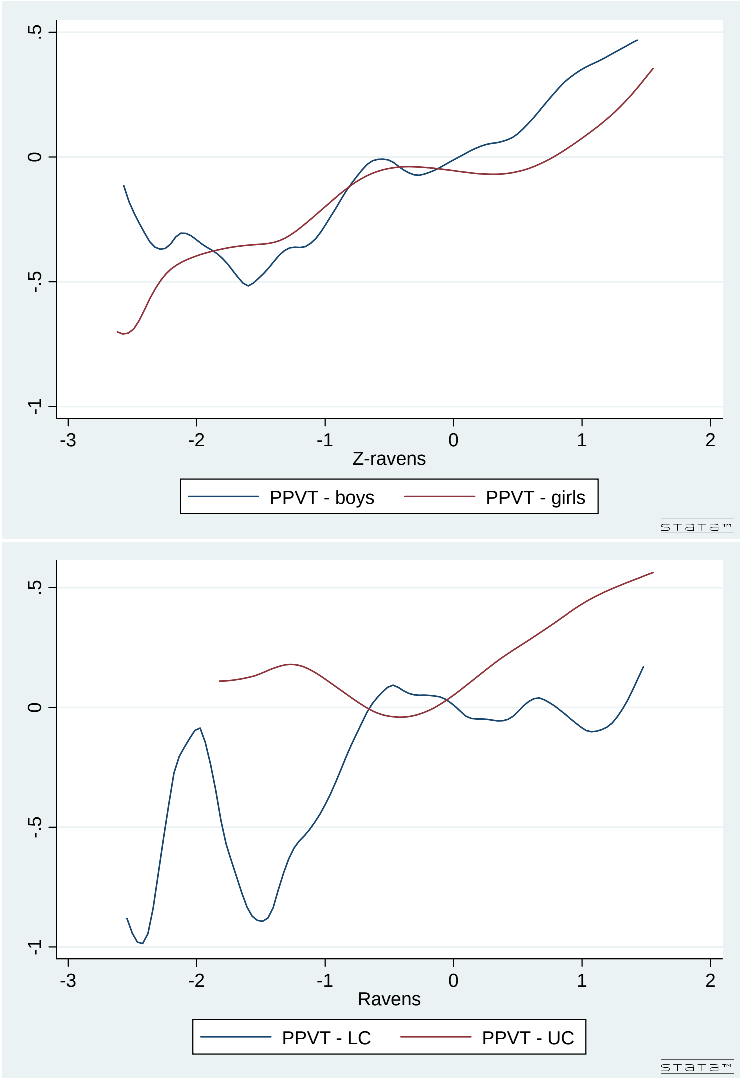
This paper has explored the determinants of children's cognitive skills using data from two cohorts of children for Andhra Pradesh, India. I do not find evidence that supports restrictive models that assume test scores depend only on contemporaneous inputs. Alternatively, the results for both cohorts show that both contemporaneous and lagged test scores (or lagged inputs) matter in the production of current skills. Results also show that it is important to allow for unobserved child-specific endowment effects and endogeneity of inputs. In models where past inputs are not observed, past nutritional status turns out to be a very good proxy-indicator of this variable. Allowing for the endogeneity of past nutrition in the OLS model using an instrumental variable approach, I find that a 1 SD increase in HAZ at the age of 1 leads to PPVT scores that are on average 24 per cent of 1 SD higher at age 5. I also find that parents are compensating (i.e., by 'purchasing' more health inputs) children for their adverse early health outcomes but reinforcing children for early favourable cognitive outcomes. The latter behaviour seems to apply mainly to boys and LC children.

Using a specification that incorporates the features above, I analyse test score gaps between LCs and UCs: the estimates show that policies that would aim to equalise HAZ and/or home inputs of UCs and LCs would close a significant proportion of the test score gap (up to a fourth of the gap for girls and a fifth for boys). However, a comparison of the efficiency of such policies would require information both about the ability of public policy to modify parental behaviour and about the costs of implementation.

In terms of further research, it might be worth analysing with the availability of Round 3 in 2010 (specifically for the Older Cohort) whether the early childhood conditions are related to later adulthood outcomes (e.g., employment, earnings, etc.). Given the fact that some of these children will become parents themselves, more information can be gathered about the inter-generational transfer of 'care-behaviour'.

Appendix Figures

Figure 1: Non parametric estimation of Ravens effects on PPVT scores



Source: Author's calculations based on YL data. Locally-weighted regression, with bandwidth=0.75 and 100 intervals to perform regressions between p1 and p99th.

Appendix 1: Cognitive tests description

The Ravens is a measure of non-verbal reasoning ability. According to its creator, the test measures the two main components of general intelligence: the ability to think clearly and make sense of complexity, which is known as eductive ability; and the ability to store and reproduce information, known as reproductive ability. However, others have interpreted this test as showing just how good visual decodification skills in children are. This test has been used to assess the cognitive abilities of children in several international studies in developing countries, such as Guatemala, Kenya, Egypt and Mexico. Factor analytical studies show that the test is a good indicator for Spearman's g-factor. The standard version of the Ravens test consists of 5 scales (A-E), with 12 items in each scale. Each item contains a figure with a missing piece, below which alternative pieces are placed to complete the figure. Each set involves a different principle for obtaining the missing piece; within a set, the items are arranged in increasing order of difficulty. According to the instructions given by the trainer, Ravens Colored Matrices version was administered. The Colored Matrices version consists of three scales: Test-A (12 items), Test-B (12 items) and Test-AB (12 items). Subscales A and B measure aspects related to cognitive processes, while subscale AB measures the intellectual capacity of the children. The test is supposed to be relatively free of cultural bias. The score is the number of correct responses to the items.

On the other hand, the PPVT is a a test of vocabulary recognition that has been widely used as a general measure of cognitive development. Earlier studies that have used the PPVT include Rosenzweig and Wolpin (1994), Blau (1991) and McCulloch and Joshi (2002). The PPVT consists of 17 sets of 12 words each. The child looks at pictures on an easel and identifies the picture which matches the word the interviewer reads out. Children start the test at a particular set depending on their age. They then move up or down depending on their responses. The response is always between 01 and 04. Training Items C and D (designed for children 8 years and older) are used for children aged 12 and Training Items A and B (designed for children under 8 years) are used for children aged 5 in the Young Lives sample. [31]

[31] Given the way I use the data in the paper, a potential concern is that children may be at different points of the distribution of ability in these two tests, even at a given age, which might make it difficult to distinguish between a true increase in relative position vis-à-vis other children versus merely having measured a different aspect of ability. However, it is unlikely that this is a big problem given the existent evidence (Butler and Hakuta 2006) of high correlation between the two instruments. One paper shows a gender differential in this respect: Garrity and Donoghue (1976) show that girls obtained a significant correlation between the PPVT raw (or non-age-corrected) scores and the Ravens, whereas boys did not.

Appendix 2: The caste system in India

The caste system is still extremely important in India in various spheres, not least politically. The 'Other Castes' (also called 'Upper Castes', as I have defined them here) category comprises mostly of 'forward castes' who traditionally enjoy a more privileged socio-economic status; at the other end of the spectrum, Scheduled Castes (SCs) and Scheduled Tribes (STs) are traditionally disadvantaged communities. SCs are the lowest in the traditional caste structure. They were formerly known as the 'untouchables' and now call themselves Dalit. In rural Andhra Pradesh, SC colonies are located separately, and in most cases away from the main villages. These colonies are named after the caste and even in the official records are often called harijana wada (or Dalit colonies). They have been subjected to discrimination for centuries and therefore had no access to basic services, including education. National legislation aims to prohibit 'untouchability' and discrimination. STs are the indigenous people, living in and dependent on forests. Different groups of tribes live in different parts of Andhra Pradesh and vary in their culture, language and lifestyles. Though a good number of them are mainstreamed and live in plain areas, a considerable proportion continues to live in isolated hilltops and has little access to services. Backward Classes (BCs) are people belonging to a group of castes who are considered to be backward in view of the low level of the caste in the structure. In Andhra Pradesh, the BCs are further divided into four groups (ABCD) and some caste groups are placed in each of these sub-groups. Recently, the High Court has ordered the inclusion of a fifth sub-group, E, and Muslims have been placed into this category.

Appendix 3: Parental investment as a latent variable and factor analysis

Parental investment is a latent variable and therefore has to be estimated given available indicators through confirmatory factor analysis. More specifically, I am interested in a single measure for the respective latent variable and therefore employ a one-factor model. In general terms, the one-factor model assumes the following form:

$$x_{it} = b_{i0t} + b_{i1t}\alpha_t + \nu_{it} \tag{8}$$

where x represents observed measures of the latent variable with $i = 1, ...m_t$ denoting the different available indicators for the specific latent variable (as listed in table 1); α_t is the factor for the latent variable (in this case, parental investment) and ν_{it} is an error term where α_t and ν_{it} are unobserved; b_{i1t} represents factor loadings and b_{i0t} is a measure-specific intercept.

In order to estimate the model, we have to make several distributional assumptions. First, the factor and the error term are uncorrelated and have an expected value of zero. Second, the errors are independent over time and across children. Thirdly, we assume that the relationship between the factor and the observed variables is linear. Finally, the scale of the common factor is fixed by setting the first factor loading equal to one. In brief, I perform a factor analysis of a correlation matrix by means of a maximum-likelihood estimation of equation (8). This analysis specifies the maximum-likelihood factor method assuming multivariate normal observations. This estimation method is equivalent to Rao's canonical-factor method, and maximises the determinant of the partial correlation matrix. Hence this solution is also meaningful as a descriptive method for non-normal data. The factor score is then predicted as the conditional mean of the latent variable given the observed variables.

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