111

Working Paper

Young Lives

An International Study of Childhood Poverty

The Structural Relationship between Nutrition, Cognitive and Non-cognitive Skills

Evidence from four developing countries

Alan Sanchez

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The data used come from Young Lives, a longitudinal study of childhood poverty that is tracking the lives of 12,000 children in Ethiopia, India (in Andhra Pradesh), Peru and Vietnam over a 15-year period. **www.younglives.org.uk**

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Contents

Abstract

Both cognitive and non-cognitive skills are rewarded in the labour market. However there is little evidence about how these abilities are formed in the context of developing countries. I study the way in which cognitive and non-cognitive skills are simultaneously acquired in the transition from childhood to adolescence using longitudinal data from four countries: Peru, India, Vietnam and Ethiopia. I estimate a linearized version of the technology of skills formation, linking inputs observed at 7 to 8 years to outputs observed at 11 to 12 and 14 to 15 years. I find evidence of self-productivity mainly for cognitive skills and cross-productivity for both types of skills. I then extend the technology of skills formation to account for the role of nutritional status in the acquisition of skills. A child's height-for-age Z-score is used as a proxy of nutritional status. To deal with the endogeneity of nutrition, this variable is instrumented using a set of selected household shocks that are country-specific. Height-for-age is found to be a relevant input in the skills formation model, having a direct as well as an indirect effect on skills accumulation. To obtain estimates of the long-term impact of nutritional investments during the early childhood period on later abilities, I use evidence gathered from a second model that links early height-for-age to cognitive ability at 7 to 8 years. Linking results from both models, I find that an increase of 1 standard deviation in early height-for-age tends to increase cognitive skills during adolescence by 6%, 9%, 17% and 7% in Peru, India, Vietnam and Ethiopia, respectively. It also increases non-cognitive skills by 2% and 4% in India and Vietnam, respectively. Finally, I test the notion of complementarity and find that the rate of return of cognitive skills is considerably lower for children that were stunted in mid childhood, whereas the rate of return of non-cognitive skills remains unchanged.

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1 Introduction

Evidence shows that both cognitive and non-cognitive skills are rewarded in the labour market (see, for instance, Heckman et al., 2006). It is also understood that abilities are shaped during the childhood period and that parental investments play an important role in this process (Cunha and Heckman, 2007). One key type of investment that influences the process of acquisition of skills is nutritional intake during the first years of life. There is evidence from developing countries linking early undernutrition to lack of opportunities later in life. The nutrition-cognition nexus is the channel most widely cited as the reason why this occurs. Early undernourished children learn less at school and have lower educational achievement (Alderman et al., 2006; Hoddinott and Kinsey, 2001). Evidence also shows that undernourished children start school later (Glewwe and Jacoby, 1995). Possibly as a consequence of these factors, children that suffered from undernutrition early in life earn less in the labour market (Maluccio et al., 2009). Recent evidence also points out to the fact that there is association between height in early and mid childhood and psychosocial competencies measured during late childhood (Dercon and Sánchez, 2013; Chang et al., 2002; Walker et al., 2007).

The aim of this paper is to shed light on the dynamic relationship between nutritional status, cognitive skills and non-cognitive skills in the childhood period in the context of countries where early undernutrition is widespread. The contribution is as follows. First, I use longitudinal data from the Young Lives study to replicate the skills formation model (Cunha and Heckman, 2008) for four developing countries and test the notions of self-productivity (more skills accumulated in the present period leads to more skills accumulated in the next period) and cross-productivity (cognitive skills reinforce non-cognitive skills, and vice versa) in the transition from mid childhood (ages 7 to 8) to adolescence (ages 14 to 15). Second, I estimate an extended version of the skills formation model in which an indicator of nutritional status is allowed to play a role. Given the importance of this dimension to explain child outcomes in the context of developing countries, this might solve omitted variable bias problems. Third, I test the concept of direct complementarity by allowing the rate of return of skills to vary according to whether the child was stunted in mid childhood. Fourth, using data from the same study but from a different age cohort, I estimate a model of cognitive skills formation that links early nutritional status (ages 1 to 2) to cognitive skills and nutritional status at ages 7 to 8. I put together these results to calculate the long-term impact of nutritional status during infancy on skills accumulated up to the age of 14 to 15.

Following Cunha and Heckman (2008) and Helmers and Patnam (2011), I estimate an extended, linear version of the skills formation model. Skills and parental investments are unobserved. These dimensions are recovered using confirmatory factor analysis. I use height-for-age as an indicator of nutritional status. This follows the notion that, when measured early in life, height-for-age is a stock variable that summarizes the history of investments in the child (Habicht et al., 1974). To deal with the endogeneity of nutritional status, height-for-age in each age period is instrumented using a set of (country specific) household shocks that took place 1 to 3 years prior to the survey year. In addition, height-for-age at 1 to 2 is instrumented using birth size and other health related aspects observed during the pregnancy period.

To carry out the analysis I use longitudinal data from the Young Lives study for four countries: Ethiopia, Vietnam, India and Peru. Data comes from two cohorts in each country: a Younger Cohort born in 2001-02 observed at 1 to 2, 4 to 5 and 7 to 8 years; and, an Older Cohort born in 1994-95 observed at 7 to 8, 11 to 12 and 14 to 15 years. The information available include anthropometric indicators, household and community characteristics for each of the observed age periods. Children scores on cognitive tests are observed in both cohorts. Results in non-cognitive tests are only observed for more than one age-period in the Older Cohort. I use data from the Older Cohort to estimate the extended version of the skills formation model. I also use data from the Younger Cohort to obtain estimates of the impact of nutritional status at the age of 1 to 2 on cognitive skills and nutritional status at the age of 7 to 8. These results are then used to study the impact of early nutrition on skills accumulated at different stages of childhood and adolescence (in the Older Cohort).

The paper is organized as follows. In Section 2 a conceptual motivation of our study is provided by sketching a simple human capital model to explain our ideas. Section 3 describes the empirical strategy used to estimate the model. Section 4 presents the data. Section 5 presents the results of estimating two versions of the skills formation model using data from the Older Cohort, including an extended version of the model where nutritional status is allowed to play a role. Sections 6 and 7 provide additional insights about the impact of nutritional status on the skills formation process.

2 Theoretical framework

To set up ideas about the hypothesized structural relationship between nutritional status and skills I sketch a human capital technology where these two dimensions are explicitly linked. To do this I extend the framework proposed by Cunha and Heckman (2007, 2008). Denote the stock of cognitive and non-cognitive skills in a given period t as θ_t^C and θ_t^{NC}, respectively. Suppose θ_t^C is acquired through the following technological process,

$$\theta_t^C = f^C(\theta_{t-1}^C, \theta_{t-1}^{NC}, H_{t-1}, I_t) \tag{1}$$

where θ_{t-1}^C and θ_{t-1}^P stand for cognitive and non-cognitive skills accumulated up to t-1 (respectively); H_{t-1} stands for a stock variable that summarizes the nutritional history of the child up to t-1; and, I_t denotes contemporaneous parental investments in skills; $t = 1, 2, \ldots, T$. An analogous equation can be defined for the production of non-cognitive skills in period t,

$$\theta_t^{NC} = f^{NC}(\theta_{t-1}^C, \theta_{t-1}^{NC}, H_{t-1}, I_t) \tag{2}$$

whereas the nutritional indicator is assumed to be a function of lagged skills, lagged nutrition and parental investments in nutrition,

$$H_t = f^H(\theta_{t-1}^C, \theta_{t-1}^{NC}, H_{t-1}, I_t^H) \tag{3}$$

which allows for the possibility that abilities might have a direct effect on nutritional status (other things equal, smarter children might take better care of themselves). The sketched technology features a situation in which past nutritional status act as an input for current cognitive and non-cognitive skills. In the case where more than two periods are observed, the earliest indicator of nutrition (period 1) can have an indirect effect on skills of later periods by affecting the stocks from intermediate periods. If period 1 is the early childhood period, one could trace the accumulated impact of nutritional investments on the formation of skills all the way to period T. The optimal allocation of I_t and I_t^H over $t = 1, 2, \ldots, T$ can be modeled as part of a maximization problem whereby parents decide how to allocate resources between consumption and investments in the child over time subject to preferences, budget constraints and initial conditions. Initial conditions can include child and household exogenous characteristics that affect the rate of return of these investments (for instance, child's genes endowment, household cognitive and non-cognitive environment, etc). Assuming the utility function and equations 1, 2 and 3 satisfy the regularity conditions, a maximization process would yield optimal allocations for consumption and investments as a function of preferences, prices and initial conditions.

3 Empirical strategy

Based on the conceptual model sketched, I estimate a linear structural model in which skills and nutritional status in period t (θ_t^C, θ_t^{NC} and H_t, respectively) are each a function of skills, and nutritional status accumulated up to period $t-1$ (θ_{t-1}^C, θ_{t-1}^{NC} and H_{t-1}, respectively) as well as dependent of contemporaneous parental investments in skills and nutrition (I_t and I_t^H, respectively). Anticipating the structure of the data available for the Young Lives Older Cohort (children observed at ages 7 to 8, 11 to 12 and 14 to 15) the following model is proposed:

$$\theta_{14-15}^C = \alpha_{11} + \alpha_{12}\theta_{11-12}^C + \alpha_{13}\theta_{11-12}^{NC} + \alpha_{14}H_{11-12} + \alpha_{15}I_{14-15} + \epsilon_1 \tag{4}$$

$$\theta_{14-15}^{NC} = \alpha_{21} + \alpha_{22}\theta_{11-12}^C + \alpha_{23}\theta_{11-12}^{NC} + \alpha_{24}H_{11-12} + \alpha_{25}I_{14-15} + \epsilon_2 \tag{5}$$

$$H_{14-15} = \alpha_{31} + \alpha_{32}\theta_{11-12}^C + \alpha_{33}\theta_{11-12}^{NC} + \alpha_{34}H_{11-12} + \alpha_{35}I_{14-15}^H + \epsilon_3 \tag{6}$$

In turn:

$$\theta_{11-12}^C = \beta_{11} + \beta_{12}\theta_{7-8}^C + \beta_{13}\theta_{7-8}^{NC} + \beta_{14}H_{7-8} + \beta_{15}I_{11-12} + \epsilon_4 \tag{7}$$

$$\theta_{11-12}^{NC} = \beta_{21} + \beta_{22}\theta_{7-8}^C + \beta_{23}\theta_{7-8}^{NC} + \beta_{24}H_{7-8} + \beta_{25}I_{11-12} + \epsilon_5 \tag{8}$$

$$H_{11-12} = \beta_{31} + \beta_{32}\theta_{7-8}^C + \beta_{33}\theta_{7-8}^{NC} + \beta_{34}H_{7-8} + \beta_{35}I_{11-12}^H + \epsilon_6 \tag{9}$$

where ϵ stands for the error term. Variables θ_K^C and θ_K^{NC} as well as I_K and I_K^H are treated as latent factors. For cognitive and non-cognitive abilities, I take advantage that the same tests have been administered in different age periods to the same children to estimate one-factor linear measurement models that link the latent factors to observed indicators. In particular, three cognitive indicators and three non-cognitive indicators are observed in each age period –the exception are non-cognitive indicators at ages $7-8$, which are not observed. Denote these indicators as $Y_{j,t}^C$ and $Y_{j,t}^{NC}$ for age periods $t = 7-8, 11-12, 14-15$ and indicators $j = 1, 2, 3$, respectively. Then,

$$Y_{j,t}^C = \alpha_{j,t}^C + \beta_{j,t}^C \theta_t^C + \epsilon_{j,t}^C \tag{10}$$

$$Y_{j,t}^{NC} = \alpha_{j,t}^{NC} + \beta_{j,t}^{NC} \theta_t^{NC} + \epsilon_{j,t}^{NC} \tag{11}$$

where θ_T^C and θ_T^{NC} are the latent factors of interest; $\epsilon_{j,t}^C$ and $\epsilon_{j,t}^{NC}$ are assumed to be classical errors. The coefficients β are known as factor loadings. Their relative magnitude allows to understand to what extent an observed indicator is driven by the latent factor. Normalizing $\beta_{1,t}^C$ and $\beta_{1,t}^{NC}$ to 1 and setting $E(S_T^C) = E(S_T^C) = 0$ it is possible to recover the remainder parameters in equations 4 to 9. These estimated parameters can be used to recover the unobserved cognitive and non-cognitive latent factors.

A similar strategy is used to recover latent factors for parental investments. In this case the focus is on variables that measure both the quantity of resources devoted to the child (in terms of time and money) as well as the quality of the relationship between the parent and the child (self-reported by the child). Due to the structure of the model, a distinction is made between indicators of parental investments in skills and indicators of parental investments in nutrition (denoted as $PS_{j,t}$ and $PH_{j,t}$ for $j = 1, 2, 3$, respectively). Formally,

$$PS_{j,t} = \alpha_{j,t}^{PS} + \beta_{j,t}^{PS} I_t + \epsilon_{j,t}^{PS} \tag{12}$$

$$PH_{j,t} = \alpha_{j,t}^{PH} + \beta_{j,t}^{PH} I_t^H + \epsilon_{j,t}^{PH} \tag{13}$$

I recover each of the latent factors presented above using factor analysis techniques. I then plug these latent factors into the structural model. The structural parameters in 4 to 9 can be recovered assuming the new error terms are uncorrelated with the unobserved skills and parental investments. I estimate versions of the model with classical error as well as allowing correlation between the error terms of the contemporaneous equations. The model is estimated by maximum likelihood.[1] Joint normality of all variables introduced in the model is assumed. Due to data constraints, I am forced to assume that $\beta_{13} = \beta_{23} = \beta_{33} = 0$.

In the case of H_t, an observable indicator is included in the specification (height-for-age, see Section 4). Since nutritional status could be correlated with unobservable traits in turn correlated with skills, there is an endogeneity problem that needs to be addressed. To deal with this aspect, a

[1] SEM command in STATA 12.

selected set of household economic shocks that are arguably uncorrelated with child unobservable characteristics are used to instrument nutritional status. The specific variables used as instruments are presented in the next section.

4 Data aspects

4.1 Data

I use data from the Young Lives Project. This is longitudinal data collected in four countries for two cohorts of children: a cohort born in 2001-02 (Younger Cohort) and a cohort born in 1994-95 (Older Cohort).[2] Both cohorts were visited on three occasions: 2002, 2006-07 and 2009. This has created a dataset that in the case of the younger cohort allows to observe the transition from early to mid childhood (1-2, 4-5 and 7-8 years) and, in the case, of the older cohort, the transition from mid to late childhood and adolescence (7-8, 11-12, 14-15). For the younger cohort, cognitive and non-cognitive data was only collected simultaneously in the third wave, whereas for the older cohort this data was collected in the second and third wave. Anthropometric data as well as household information on demographics and socio-economic status was collected on the three occasions households were visited. Tables 2 and 3 report a summary of the main variables considered for the analysis for the Younger Cohort and Older Cohort, respectively. It is important to highlight that 34, 76, 82 and 64 percent of the households sampled in Ethiopia, India, Peru and Vietnam were located in rural areas (respectively)[3] at the time of the first interview, so the urban/rural distinction is a relevant aspect to address.

4.2 Factor analysis for skills and parental investments

Multiple cognitive and non-cognitive indicators are observed for the Young Lives Older Cohort. This is the raw data used to estimate skills. On the cognitive area, one key indicator is a child's score in the Peabody Picture Vocabulary Test (PPVT). The PPVT is a test of receptive vocabulary. A child is said a word and must choose between four pictures the picture that is more closely related to the word. The items used were validated independently for local teams in each country and are age-standardized. Besides the PPVT, a numeracy test and a writing and reading comprehension test were administered. Details of the design of these tests can be obtained in Cueto et al. (2009) and Cueto and Leon (2009). In addition, the Raven test was administered to the Older Cohort only in the first wave of data collection, when children aged 7 to 8.

In the case of the non-cognitive indicators, three indicators were considered: self-esteem, self-efficacy and self-respect. Self-esteem and self-efficacy are notions that have been validated in the

[2] To select the children in each country a multi-stage sampling procedure was used. Firstly, twenty clusters were selected from each country (clusters are, typically, geo-political units such as districts in Peru). Secondly, within each cluster, a village/town (or a group of villages/towns) and a group of eligible households within each village/town was chosen at random, respectively. For the Younger Cohort (Older Cohort) the household eligibility criterion consisted in having a child aged 6 to 24 months (7 to 8 years) at the time of the first interview. Both cohorts were sampled from the same clusters. Typically, 100 children were sampled in each cluster in the Younger Cohort (50 children in the Older Cohort).

[3] In the Younger Cohort. Figures are similar for the Older Cohort.

psychological literature and that are correlated with economic and social outcomes later in life. Self-esteem is related to a person's overall evaluation of her own worth. In turn, self-efficacy is related to a person's sense of agency or mastery over his life. To measure these two psychosocial traits, average scores were constructed based on children answers to a number of statements. As explained in (Dercon and Sánchez, 2013) the statements used for the construction of each index were drawn from the educational psychology literature, adapted and tested during piloting for use with children across different cultures. In addition to self-esteem and self-efficacy I consider a third dimension: self-respect. The statements used to measure self-respect revolve around the concepts of pride and sense of inclusion. While this dimension has not been validated in the psychological literature, the statistical analysis suggests that self-respect score co-move with self-esteem and self-efficacy, suggesting they are influenced by a common factor.

Using this data, cognitive and non-cognitive skills were obtained through confirmatory factor analysis for each country sample and for each age-period. Tables 4 and 5 report the factor loadings obtained. The models have a good fit according to the RMSEA, CFI and TLI. The factor loadings have the expected sign and they are statistically significant. The histograms of these factors are shown in figures 1 and 2.

To recover parental investments in skills, indicators were selected that contain information about parental resources devoted to the child in terms of money and time as well as the quality of the relationship between the parent and the child. Three variables were selected for this purpose: (a) expenditure in non-food items specifically devoted to the child (this includes expenditure in education, clothes and entertainment); average number of hours during which the child studies at home (as a proxy for the time that parents dedicate to the child); (c) and, an indicator of the type of relationship that the child has with his parents [4] (answered through a self-administered questionnaire). The indicator is standardized to have mean zero and variance one. A higher level of the indicator implies that the child has a better relationship with his parents. It is assumed that parental investments in skills is the latent factor that governs these three selected indicators. Finally, I use household per capita expenditure in five food groups as observable indicators of parental investments in nutrition. The results of the factor analysis are reported in tables 6 and 7.

4.3 Measurement of nutritional status

Child's height-for-age z-score is used as an indicator of nutritional status. It is well established that, on average, preschool-aged children have the same physical growth potential, regardless of genetic or ethnic backgrounds, and that linear growth retardation at the first few years is mainly the result of an inadequate nutrition over an extended period of time (Martorell, 1999). The World Health Organization (WHO) estimates growth standards for children aged less than 5 years old, which are used to assess chronic malnutrition. Similarly, WHO estimates growth references for school-aged

[4]This indicator is the average score of the following items: "I usually feel able to speak my views and feelings with my parents"; "Most of the time my parents treat me fairly when I do something wrong"; "Compared to my sisters fewer things are provided for me"; "Compared to my brothers fewer things are provided for me"; "Compared to my sisters I have less freedom to leave the house when I want"; "Compared to my brothers I have less freedom to leave the house when I want".

children and adolescents. The existence of a growth reference for school-aged children is based on the evidence that shows limited variation in the mean height of well nourished children from different ethnic backgrounds up to puberty. See, for instance, Haas and Campirano (2006). To use these growth curves, height is transformed into height-for-age z-scores that measure the distance between a given child and the norm child for the corresponding age and sex.

Height-for-age is observed in the Older Cohort at ages 7 to 8, 11 to 12 and 14 to 15. Particular attention is put on height-for-age at ages 7 to 8, as this is the earliest measurement of height observed in the system of equations, thus conveying information of investments on the child during the first years of life. Although conceptually an earlier measure of height-for-age would be desirable to capture early-life nutritional investments –e.g., due to the possibility of nutritional catch-up–, it is important to note the following. First, by the standards of the related literature this indicator is measured early enough to be informative of nutritional investments (Habicht et al., 1974). Second, the indicator is observed before puberty, a stage when genetic disparities in physical height across ethnic groups become more pronounced. Third, to statistically test whether physical height at the age of 7 to 8 conveys information from the first few years of life I used data from the Younger Cohort to show that the correlation between height-for-age at 1 to 2 and at 7 to 8 is 0.69. Overall, this gives sufficient ground to use height-for-age 7 to 8 as a nutritional indicator. The percentage of children classified as stunted using this indicator fluctuates between 24 and 29 per cent in the country samples. As expected, the samples with a higher proportion of children living in poverty (Ethiopia and India) report the highest levels of stunting.

To deal with the endogenous nature of height-for-age, when included in the model it is instrumented using a set of self-reported household shocks that took place 1 to 3 years prior to each of the surveys.[5] These shocks include natural disasters (drought, flood, frosts, etc), illness of a household member, job loss, theft, etc. The shocks selected vary by country and were chosen only when at least 5% of the sample was affected by them.

5 Main results

I first estimate the standard skills formation model and then proceed to extend it to take into account the role of height-for-age. In addition to the model specification presented in Section 3, all equations control for whether the household is located in a rural area and for maternal schooling (in years of education). It can be argued that both variables are inputs in the technology of skills formation. All equations control for year of birth of the child, and, in those equations where height-for-age at 11 to 12 is an independent variable, an indicator of whether the child has reached puberty is included as a control. Variables are standardized to have mean zero and variance one.

The first set of results is reported in Table 8. Since these results do not include height-for-age as an input, results can be compared with previous findings from the literature in skills formation. Two concepts of interest are self-productivity (more skills accumulated in the present period leads to more skills accumulated in the next period) and cross-productivity (cognitive skills reinforce

[5]Unfortunately, the exact timing is unknown.

non-cognitive skills, and vice versa). Using data from the US, Cunha and Heckman (2008) find evidence of self-productivity for both types of abilities. In turn, they obtain evidence of cross-productivity from non-cognitive to cognitive skills, but not viceversa. Using data from the Young Lives sample from India, Helmers and Patnam (2011) find that cognitive skills are relevant to predict later cognitive skills (self-productivity) and non-cognitive skills (cross-productivity). On the other hand, they find that non-cognitive skills are not relevant to predict later skills.

In this analysis I find evidence of self-productivity and cross-productivity. In particular, I find that cognitive skills at 14 to 15 are predicted both by cognitive skills (self-productivity) and by non-cognitive skills (cross-productivity) accumulated up to the age of 11 to 12. This result is consistent across countries. This finding is consistent with Cunha and Heckman but not with Helmers and Patnam. Similarly, my results highlight the importance of parental investments in the skills formation process. In addition, the control variables added to take into account parental investments and other household characteristics explain an important proportion of the variation in cognitive skills in all countries.

In terms of what drives non-cognitive skills at 14 to 15, the main pattern observed is that contemporaneous parental investments play an important role. As for the role of lagged skills, the evidence is somewhat mixed. I find evidence of cross-productivity in only two countries (Peru and India) and evidence of self-productivity in only one country (Vietnam). Since coefficients are considerably heterogenous, it is difficult to generalize results for these concepts.

As for skills accumulated at the age of 11 to 12, parental investments play a key role as an input for both types of abilities. Finally, cognitive skills accumulated up to the age of 7 to 8 also play an important role in the formation of both types of skills. It is important to note that cognitive ability at 7 to 8 is in turn a function of earlier parental investments in skills and nutrition. This variable is the only one in this specifications that embodies investments made on the child during the critical first few years of life. This is an aspect to which I come back later.

Table 9 presents results of an extended version of the skills formation model in which lagged height-for-age (instrumented using household shocks) is added as an input. The magnitude of the self-productivity and cross-productivity coefficients remains virtually unchanged, suggesting the initial specification did not suffer from omitted variable bias due to the exclusion of a nutritional indicator. In this new specification, particular attention must be paid to the role of height-for-age at 7 to 8 –the earliest measurement of nutritional status available– as a direct determinant of skills at 11 to 12 and as an indirect determinant of skills at 14-15. The evidence of the role of height-for-age during this age period is mixed. An increase by 1 standard deviation in height-for-age at 7 to 8 tends to increase cognitive skills at 11 to 12 by 17% and 8% in Vietnam and Ethiopia, respectively, whereas the effect for Peru and India is statistically insignificant. Similarly, an increase by 1 standard deviation in height-for-age at 7 to 8 tends to increase non-cognitive skills at 11 to 12 by 12% and 7% in Peru and Vietnam, respectively; but the same effect is statistically insignificant for India and Ethiopia. While results suggest that height-for-age might play a role in the development of skills, it is difficult to establish a generalization given how results differ by country.

6 Assessing the long-term impact of early nutrition on skills formation

The previous model provides a framework to understand the dynamic relationship between nutritional status and skills. However, it is important to recognize that cognitive ability at 7-8 is, by construction, determined by earlier parental investments in skills and nutrition. Since in the results cognitive ability at 7-8 has a strong predictive power in the determination of cognitive and non-cognitive ability at later ages, it follows that previous estimates of the impact of nutrition in the skills formation process are likely to be very conservative, since the impact of very early investments in nutrition is not being captured. While for the Older Cohort it is not possible to observe earlier measurements of height and skills, data from the Younger Cohort can be used to obtain estimates of the marginal effect of early-life nutritional status on cognitive skills and nutritional status at 7 to 8 years; exactly the same age period observed in the first round of data available for the Older Cohort. Then, coefficients of both models can be used to extrapolate the impact of an improvement in early height-for-age on skills at later stages of childhood.

Using data from the Young Cohort a model of cognitive skills formation is estimated in which cognitive ability is a function of lagged cognitive ability, lagged nutritional status and contemporaneous parental investments. Similarly, nutritional status is a function of lagged ability, lagged nutrition and parental investments in nutrition. This framework is consistent with models of early childhood development. See, for instance, Alderman et al. (2006). Nutritional status is observed at 1 to 2, 4 to 5 and 7 to 8 years; multiple cognitive indicators are observed at 4 to 5 and 7 to 8 years. As before, cognitive skills and parental investments are recovered through confirmatory factor analysis, whereas a child's height-for-age Z-score is used to proxy his nutritional status. Height-for-age is instrumented by a set of (country specific) household shocks. In addition, height-for-age at 1 to 2 years is further instrumented using child's birth size, mother's health status during pregnancy (both self-reported by the mother), place of birth (home/health facility) and number of antenatal visits made by the mother. Results of this estimation are presented in Table 10. The results show that a 1 standard deviation improvement in height-for-age at 4 to 5 years tends to increase cognitive ability at 7 to 8 years by 9%, 15%, 11% and 11% for Peru, India, Vietnam and Ethiopia, respectively. It also increases height-for-age at 7 to 8 by 75%, 73%, 79% and 64% (respectively).

Table 1 summarizes the direct effects of lagged nutritional status on cognitive and non-cognitive skills obtained from both models. The largest impact of nutritional status on skills is observed during the early childhood period. From these results, linking the coefficients from both models it can be extrapolated that a 1 standard deviation improvement in height at 4-5 years tends to increase cognitive ability during adolescence (14-15) by 6%, 9%, 17% and 7% in Peru, India, Vietnam and Ethiopia, respectively; non-cognitive ability improves by 2% and 4% in India and Vietnam; and, improves height by 49%, 42%, 54% and 37%, respectively.

7 Complementarities between stunting and skills

Results suggest that nutritional status play a role in the formation of skills in late childhood and, subsequently, in adolescence, but mostly for cognitive skills. Motivated by this evidence I proceed to estimate the concept of direct complementarity between cognitive skills and an indicator of nutritional status. In particular, I consider the possibility that stunting in mid childhood can affect the rate of return of cognitive skills. This aspect is modeled by allowing productivity of cognitive skills to vary according to whether the child was moderately or severely stunted in mid childhood (height-for-age Z-score below -2 and -3, respectively). See results in Table 11. Results show that stunting in mid childhood shifts down the rate of return of cognitive skills. In other words, on average stunting makes any additional investment in cognitive skills less profitable in terms of skills accumulation.

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Appendix

Table 1: Direct effects of nutritional status on cognitive skills under alternative definitions of nutrition

	Peru (1)	India (2)	Vietnam (3)	Ethiopia (4)
Dependent variable: cognitive skills, age 14-15				
Height-for-age, age 11-12	0.045	0.082**	0.131***	0.062*
	(0.032)	(0.033)	(0.042)	(0.032)
Dependent variable: non-cognitive skills, age 14-15				
Height-for-age, age 11-12	-0.049	0.018	0.045	-0.03
	(0.039)	(0.040)	(0.038)	(0.073)
Dependent variable: cognitive skills, age 11-12				
Height-for-age, age 7-8	0.026	0.054	0.156***	0.070**
	(0.038)	(0.041)	(0.042)	(0.028)
Dependent variable: non-cognitive skills, age 11-12				
Height-for-age, age 7-8	0.123***	-0.030	0.074**	-0.016
	(0.042)	(0.034)	(0.037)	(0.053)
Dependent variable: cognitive skills, age 7-8				
Height-for-age, age 4-5	0.122***	0.169***	0.172***	0.111***
	(0.025)	(0.031)	(0.034)	(0.021)
Dependent variable: cognitive skills, age 4-5				
Height-for-age, age 1-2	0.136***	0.179***	0.143***	0.099**
	(0.036)	(0.030)	(0.047)	(0.046)

Notes: (a) Standard errors in parenthesis. (b) All variables are standardized with mean 0 and variance 1. (c) Classical errors are assumed.

Table 2: Descriptive statistics for the 4 countries (Younger Cohort)

	Peru		**India**		**Vietnam**		**Ethiopia**		**Full sample**	
Variable	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Mother's education	8.12	6.59	3.84	5.86	7.78	8.42	3.87	9.18	5.96	7.86
% of female child	49.97	50.01	46.08	49.86	48.70	50.00	47.11	49.93	47.98	49.96
% of rural households	33.52	47.22	75.61	42.96	81.81	38.58	63.61	48.13	63.56	48.13
Round 1										
Age of child (in years)	0.96	0.29	0.99	0.29	0.97	0.26	0.97	0.30	0.97	0.29
height-for-age z-score	-0.74	1.30	-0.82	1.53	-0.52	1.15	-1.04	1.85	-0.77	1.48
% of stunted children	16.52	37.14	19.52	39.65	9.14	28.83	30.14	45.90	18.47	38.80
Round 2										
Age of child (in years)	5.29	0.39	5.36	0.32	5.26	0.31	5.15	0.32	5.27	0.34
height-for-age z-score	-1.47	1.09	-1.61	0.99	-1.28	1.02	-1.40	1.11	-1.44	1.06
% of stunted children	30.88	46.21	34.31	47.49	22.86	42.01	29.56	45.64	29.32	45.52
PPVT test score	0.00	0.99	0.00	0.99	0.01	0.98	0.03	1.03	0.01	1.00
Math test score	0.01	0.99	-0.02	1.00	0.02	0.99	0.02	1.00	0.01	1.00
Consumption in food (per capita)	46.92	36.12	26.77	19.37	0.05	0.03	29.90	21.62	25.91	28.74
Consumption in non-food items exclusive to YL child	16.88	23.50	8.69	18.69	0.02	0.03	5.61	10.56	7.92	17.23
Average hours of studying outside school in home	1.58	1.66	1.43	2.37	1.29	4.41	0.93	0.84	1.33	2.67
Round 3										
Age of child (in years)	7.95	0.30	7.99	0.33	8.08	0.32	8.11	0.31	8.03	0.32
height-for-age z-score	-1.14	1.03	-1.45	1.02	-1.08	1.04	-1.20	1.13	-1.21	1.07
% of stunted children	19.48	39.62	29.99	45.83	18.99	39.23	21.12	40.83	22.35	41.66
PPVT test score	0.02	0.98	0.00	0.99	0.03	0.99	0.04	1.02	0.02	1.00
Math test score	0.02	0.99	-0.01	0.99	0.00	1.00	0.02	1.01	0.00	1.00
EGRA test score	0.01	0.99	0.00	0.98	0.03	0.95	0.04	1.01	0.02	0.98
Self-esteem score	-0.01	1.00	0.01	1.00	0.01	1.00	0.02	1.00	0.01	1.00
Self-efficacy score	0.00	1.00	0.01	1.00	0.01	0.99	0.02	1.00	0.01	1.00
Consumption in food (per capita)	48.08	37.69	29.32	16.05	0.06	0.03	24.56	14.65	25.61	28.04
Consumption in non-food items exclusive to YL child	34.18	46.51	15.52	16.02	0.02	0.03	5.95	10.83	14.25	28.77
ÃĐndex of relationship with parents	0.02	0.98	-0.01	1.01	0.07	0.94	-0.01	1.00	0.02	0.98
Hours of studying outside school	1.89	0.84	1.83	1.07	2.90	1.50	1.04	0.88	1.93	1.27
Number of observations	1631		1433		1294		1624		5994	

Notes: Cognitive test scores are standardized by age (in years) and by country to have mean 0 and variance 1. Non-cognitive test scores are standardized by country. 2. Both Consumption in food and Consumption in non-food items exclusive to YL child are in dolars adjusted by PPA.

Table 3: Descriptive statistics for the 4 countries (Older Cohort)

	Peru		India		Vietnam		Ethiopia		Full sample	
Variable	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Mother's education	7.35	4.42	3.06	4.41	7.12	3.89	2.68	3.85	5.07	4.67
% of female child	47.35	49.98	49.60	50.03	51.36	50.01	48.86	50.03	49.53	50.01
% of rural households	25.96	43.88	74.34	43.71	80.24	39.84	63.40	48.21	64.11	47.98
Round 1										
Age of child (in years)	8	0.33	8	0.32	8	0.27	8	0.29	8	0.30
height-for-age z-score	-1.34	1.01	-1.48	1.02	-1.38	0.96	-1.43	1.27	-1.41	1.06
% of stunted children	24.86	43.26	28.99	45.40	25.92	43.84	29.41	45.60	27.32	44.57
Raven test score	0.02	0.99	0.01	1.00	0.01	0.97	0.07	1.01	0.02	0.99
Round 2										
Age of child (in years)	12	0.47	12	0.35	12	0.33	12	0.32	12	0.38
height-for-age z-score	-1.45	1.05	-1.45	1.02	-1.36	1.05	-1.30	1.21	-1.39	1.08
% of stunted children	28.15	45.02	30.19	45.94	27.57	44.72	27.29	44.58	28.34	45.07
PPVT test score	0.03	0.98	0.12	0.94	0.08	0.88	0.08	0.99	0.08	0.94
Math test score	0.02	0.98	0.17	0.86	0.11	0.85	0.10	0.95	0.10	0.90
Self-esteem score	0.01	1.00	0.06	0.95	0.03	0.99	0.08	0.99	0.04	0.98
Self-efficacy score	0.01	0.99	0.06	0.95	0.02	0.96	0.03	0.99	0.03	0.97
Self-respect score	0.01	0.99	0.07	0.92	0.00	1.00	0.05	0.94	0.03	0.96
Consumption in food per month (per capita)	28.05	16.63	9.70	10.49	0.02	0.01	8.02	4.52	10.00	13.62
Consumption in non-food items exclusive to YL child per month	8.47	12.81	4.92	6.29	0.01	0.01	1.74	2.27	3.41	7.37
ÃĎndex of relationship with parents	0.03	0.98	0.03	0.99	0.02	1.01	0.04	0.99	0.03	0.99
Hours of studying outside school	3.01	1.28	2.04	1.31	3.00	1.55	1.85	1.02	2.48	1.42
Round 3										
Age of child (in years)	15	0.38	15	0.35	15	0.34	15	0.30	15	0.35
height-for-age z-score	-1.45	0.90	-1.56	1.00	-1.39	0.89	-1.35	1.27	-1.44	1.02
% of stunted children	24.86	43.26	28.99	45.40	25.92	43.84	29.41	45.60	27.32	44.57
PPVT test score	0.02	0.97	0.11	0.95	0.10	0.89	0.08	0.98	0.08	0.94
Math test score	0.02	0.99	0.07	1.02	0.06	0.96	0.08	1.01	0.06	0.99
CLOZE test score	0.02	0.98	0.05	1.00	0.07	0.93	0.05	1.03	0.05	0.98
Self-esteem score	0.01	0.98	0.01	1.01	0.02	1.00	0.06	0.97	0.02	0.99
Self-efficacy score	0.01	0.99	0.07	0.94	0.04	0.97	0.05	0.99	0.05	0.97
Self-respect score	0.00	1.00	0.08	0.92	0.01	1.00	0.06	1.00	0.04	0.98
Consumption in food per month(per capita)	33.00	19.42	11.20	6.78	0.02	0.01	8.88	5.28	11.58	15.07
Consumption in non-food items exclusive to YL child per month	19.13	28.27	7.84	9.96	0.01	0.02	2.58	4.06	6.51	15.41
ÃĎndex of relationship with parents	0.01	0.99	0.01	0.99	0.03	0.95	-0.04	1.01	0.01	0.98
Hours of studying outside school	2.14	1.10	2.19	1.47	3.20	2.09	1.96	1.27	2.43	1.67
Number of observations	523		739		805		604		2671	

Notes: Cognitive test scores are standardized by age (in years) and by country to have mean 0 and variance 1. Non-cognitive test scores and Ãŋndex of relationship with parents are standardized by country. 2. Both Consumption in food and Consumption in non-food items exclusive to YL child are in dolars adjusted by PPA.

Table 4: Factor loadings for cognitive skills (Older Cohort)

	Peru	India	Vietnam	Ethiopia
PANEL A: Independent variable is the cognitive latent skill in round 3				
PPVT test score	1	1	1	1
Math test score	0.838***	1.094***	1.334***	1.343***
	(0.046)	(0.053)	(0.086)	(0.100)
EGRA test score	1.022***	1.125***	1.191***	1.547***
	(0.049)	(0.054)	(0.075)	(0.122)
RMSEA	0.00	0.00	0.00	0.00
CFI	1.00	1.00	1.00	1.00
TLI	1.00	1.00	1.00	1.00
PANEL B: Independent variable is the cognitive latent skill in round 2				
PPVT test score	0.772	0.788	0.820	0.683
	(941.721)	(181.410)	(153.308)	(100.204)
Math test score	0.772	0.788	0.820	0.683
	(941.721)	(181.410)	(153.308)	(100.204)
RMSEA	0.00	0.00	0.00	0.00
CFI	1.00	1.00	1.00	1.00
TLI	1.00	1.00	1.00	1.00
PANEL C: Independent variable is the cognitive latent skill in round 1				
Raven test score	1	1	1	1
Writing's level	0.960***	3.199**	0.882*	1.034***
	(0.211)	(1.309)	(0.466)	(0.260)
Math question	1.630***	2.188***	2.201	1.001***
	(0.448)	(0.657)	(1.514)	(0.241)
RMSEA	0.000	0.000	0.000	0.000
CFI	1.000	1.000	1.000	1.000
TLI	1.057	1.063	1.248	1.075

Notes: (a) Standard errors in parenthesis. (b) All variables are standardized with mean 0 and variance 1 before the CFA analysis. (c) Classical errors are assumed.

Table 5: Factor loadings for non-cognitive skills (Older Cohort)

	Peru	India	Vietnam	Ethiopia
PANEL A: Independent variable is the non-cognitive latent skill in round 3				
Self-esteem average score	1	1	1	1
Self-efficacy average score	1.225***	1.640***	0.894***	1.603***
	(0.183)	(0.255)	(0.082)	(0.314)
Self-respect average score	1.008***	1.432***	1.059***	2.077***
	(0.148)	(0.203)	(0.099)	(0.454)
RMSEA	0.00	0.00	0.00	0.00
CFI	1.00	1.00	1.00	1.00
TLI	1.00	1.00	1.00	1.00
PANEL B: Independent variable is non-cognitive latent skill in round 2				
Self-esteem average score	1	1	0.399	1
			(252.449)	
Self-efficacy average score	0.215	0.582***	0.399	0.720***
	(0.188)	(0.103)	(252.449)	(0.128)
Self-respect average score	0.664	1.505***	.	1.794***
	(0.619)	(0.379)	.	(0.371)
RMSEA	0.00	0.00	0.00	0.00
CFI	1.00	1.00	1.00	1.00
TLI	1.00	1.00	1.00	1.00

Notes: (a) Standard errors in parenthesis. (b) All variables are standardized with mean 0 and variance 1 before the CFA analysis. (c) Classical errors are assumed. (d) This CFA analysis uses the average score of the socioemotional skills. (e) The CFA analysis of Ethiopia in round 2 does not converge. So, I use CFA excluding self-respect only in this case.

Table 6: Factor loadings for parental investment in skills (Older Cohort)

	Peru (1)	India (2)	Vietnam (3)	Ethiopia (4)
PANEL A: Independent variable is parental investment in skill at age 14-15.				
Índex of relationship with parents	1	1	1	1
Hours of study outside school	6.713*	8.844***	33.028**	3.427
	(3.926)	(2.436)	(16.268)	(2.368)
Consumption in non-food items exclusive to YL Child	622.553	94.155***	0.510**	136.819
	(649.153)	(18.847)	(0.200)	(260.269)
RMSEA	0.000	0.000	0.000	0.000
CFI	1.000	1.000	1.000	1.000
TLI	1.000	1.000	1.000	1.000
PANEL B: Independent variable is parental investment in skill at age 11-12.				
Índex of relationship with parents	1	1	1	1
Hours of study outside school	2.681**	7.724**	28.150	3.545
	(1.319)	(3.652)	(21.490)	(2.566)
Consumption in non-food items exclusive to YL Child	131.111	80.597**	0.253*	20.631
	(79.972)	(31.990)	(0.142)	(12.915)
RMSEA	0.000	0.000	0.000	0.000
CFI	1.000	1.000	1.000	1.000
TLI	1.000	1.000	1.000	1.000

Notes: (a) Standard errors in parenthesis. (b) All variables are standardized with mean 0 and variance 1. (c) Classical errors are assumed.

Table 7: Factor loadings for parental investment in nutrition (Older Cohort)

	Peru	India	Vietnam	Ethiopia
	(1)	(2)	(3)	(4)
PANEL A: Independent variable is parental investment in nutrition at age 11-12.				
proteins	1	1	1	1
carbohydrates	0.573***	2.129***	0.214***	2.292***
	(0.066)	(0.612)	(0.025)	(0.313)
lipids and other	0.167***	0.954***	0.087***	0.574***
	(0.026)	(0.113)	(0.017)	(0.089)
vitamins and minerals	0.306***	0.840***	0.281***	0.185***
	(0.035)	(0.091)	(0.021)	(0.042)
drinks	0.136***	0.345***	0.160***	0.327***
	(0.016)	(0.097)	(0.015)	(0.046)
RMSEA	0.000	0.013	0.049	0.000
CFI	1.000	0.998	0.981	1.000
TLI	1.000	0.996	0.961	1.005
PANEL B: Independent variable is parental investment in nutrition at age 14-15.				
proteins	1	1	1	1
carbohydrates	0.515***	1.556***	0.366***	1.885***
	(0.031)	(0.105)	(0.027)	(0.260)
lipids and other	0.192***	0.588***	0.135***	0.348***
	(0.016)	(0.037)	(0.020)	(0.059)
vitamins and minerals	0.248***	0.506***	0.373***	0.205***
	(0.015)	(0.035)	(0.024)	(0.024)
drinks	0.124***	0.150***	0.167***	0.311***
	(0.008)	(0.012)	(0.019)	(0.038)
RMSEA	0.062	0.043	0.03	0.088
CFI	0.987	0.991	0.994	0.897
TLI	0.973	0.982	0.988	0.794

Notes: (a) Standard errors in parenthesis. (b) All variables are standardized with mean 0 and variance 1. (c) Classical errors are assumed.

Table 8: Technology of cognitive and non-cognitive skills formation (Older Cohort)

	Peru (1)	India (2)	Vietnam (3)	Ethiopia (4)	Chi-square statistic	P-value
Dependent variable: cognitive skills, age 14-15						
Cognitive skills, age 11-12	0.627***	0.535***	0.468***	0.498***	58.37	0.000
	(0.036)	(0.054)	(0.035)	(0.037)		
Non-cognitive skills, age 11-12	0.125***	0.049*	0.091***	0.047	11.45	0.010
	(0.041)	(0.025)	(0.028)	(0.034)		
Parental investment in skills, age 14-15	0.105***	0.234***	0.236***	0.092	4.14	0.247
	(0.025)	(0.040)	(0.044)	(0.063)		
Maternal education	0.113***	0.128***	0.074*	0.015	5.65	0.130
	(0.031)	(0.046)	(0.038)	(0.049)		
Dependent variable: non-cognitive skills, age 14-15						
Cognitive skills, age 11-12	0.156***	0.130***	0.050	0.024	4.05	0.256
	(0.055)	(0.037)	(0.057)	(0.066)		
Non-cognitive skills, age 11-12	0.050	0.001	0.083**	0.051	6.73	0.081
	(0.054)	(0.034)	(0.037)	(0.046)		
Parental investment in skills, age 14-15	0.163***	0.168***	0.159***	0.065	8.34	0.040
	(0.053)	(0.048)	(0.056)	(0.046)		
Maternal education	0.055	0.033	0.041	-0.049	1.76	0.624
	(0.047)	(0.040)	(0.031)	(0.078)		
Dependent variable: cognitive skills, age 11-12						
Cognitive skills, age 7-8	0.339***	0.304***	0.273***	0.227***	38.05	0.000
	(0.045)	(0.040)	(0.041)	(0.040)		
Parental investment in skills, age 11-12	0.116**	0.207***	0.087*	0.213***	6.22	0.101
	(0.058)	(0.041)	(0.047)	(0.038)		
Maternal education	0.192***	0.138***	0.341***	0.106***	13.48	0.004
	(0.047)	(0.035)	(0.044)	(0.034)		
Dependent variable: non-cognitive skills, age 11-12						
Cognitive skills, age 7-8	0.107**	0.107***	0.048	0.099**	13.54	0.004
	(0.053)	(0.035)	(0.041)	(0.048)		
Parental investment in skills, age 11-12	0.132***	0.144***	0.190***	0.214***	6.24	0.100
	(0.039)	(0.044)	(0.074)	(0.053)		
Maternal education	0.203***	0.124***	0.112**	-0.040	13.69	0.003
	(0.047)	(0.045)	(0.050)	(0.064)		
n	524	786	807	705		

Notes: (a) Standard errors in parenthesis. (b) All variables are standardized with mean 0 and variance 1. (c) Classical errors are assumed. (d) All equations control for year of birth and whether the household was located in a rural area when the child aged 7-8.

Table 9: Extended technology of cognitive and non-cognitive skills formation (Older Cohort)

	Peru	India	Vietnam	Ethiopia
	(1)	(2)	(3)	(4)
Dependent variable: cognitive skills, age 14-15				
Cognitive skills, age 11-12	0.622***	0.515***	0.437***	0.489***
	(0.036)	(0.052)	(0.038)	(0.036)
Non-cognitive skills, age 11-12	0.116***	0.040	0.098**	0.055
	(0.040)	(0.031)	(0.029)	(0.037)
Height-for-age, age 11-12	0.043	0.078**	0.133***	0.071*
	(0.032)	(0.031)	(0.042)	(0.031)
Parental investment in skills, age 14-15	0.099***	0.238***	0.226***	0.079
	(0.024)	(0.043)	(0.045)	(0.059)
Maternal education	0.112***	0.118***	0.059	0.027
	(0.031)	(0.042)	(0.038)	(0.044)
Dependent variable: non-cognitive skills, age 14-15				
Cognitive skills, age 11-12	0.164***	0.138***	0.041	0.063
	(0.057)	(0.032)	(0.053)	(0.062)
Non-cognitive skills, age 11-12	0.062	-0.014	0.077**	0.051
	(0.050)	(0.038)	(0.038)	(0.047)
Height-for-age, age 11-12	-0.050	0.009	0.039	-0.061
	(0.039)	(0.040)	(0.037)	(0.069)
Parental investment in skills, age 14-15	0.169***	0.164***	0.151***	0.075*
	(0.053)	(0.043)	(0.055)	(0.044)
Maternal education	0.049	0.032	0.050	-0.020
	(0.047)	(0.043)	(0.035)	(0.065)
Dependent variable: height-for-age, age 14-15				
Cognitive skills, age 11-12	0.039	0.017	0.088***	0.026
	(0.027)	(0.020)	(0.028)	(0.033)
Non-cognitive skills, age 11-12	0.000	0.022	0.019	-0.021
	(0.032)	(0.022)	(0.017)	(0.034)
Height-for-age, age 11-12	0.868***	0.747***	0.786***	0.772***
	(0.019)	(0.026)	(0.022)	(0.023)
Parental investment in nutrition, age 14-15	-0.038**	0.013	0.051***	-0.037
	(0.019)	(0.030)	(0.019)	(0.029)
Maternal education	0.065**	0.049*	-0.022	-0.020
	(0.028)	(0.026)	(0.017)	(0.023)
Dependent variable: cognitive skills, age 11-12				
Cognitive skills, age 7-8	0.341***	0.304***	0.259***	0.207***
	(0.046)	(0.040)	(0.037)	(0.039)
Height-for-age, age 7-8	0.023	0.051	0.168***	0.080**
	(0.038)	(0.039)	(0.043)	(0.036)
Parental investment in skills, age 11-12	0.112**	0.194***	0.074	0.213***
	(0.055)	(0.044)	(0.046)	(0.037)
Maternal education	0.183***	0.133***	0.310***	0.085***
	(0.048)	(0.033)	(0.041)	(0.028)
Dependent variable: non-cognitive skills, age 11-12				
Cognitive skills, age 7-8	0.098*	0.106***	0.037	0.092*
	(0.056)	(0.030)	(0.041)	(0.047)
Height-for-age, age 7-8	0.121***	-0.006	0.073*	-0.022
	(0.045)	(0.034)	(0.038)	(0.048)
Parental investment in skills, age 11-12	0.113***	0.153***	0.173**	0.195***
	(0.033)	(0.042)	(0.075)	(0.048)
Maternal education	0.186***	0.121***	0.105**	-0.034
	(0.050)	(0.042)	(0.048)	(0.062)
Dependent variable: height-for-age, age 11-12				
Cognitive skills, age 7-8	0.020	0.008	0.011	0.036
	(0.027)	(0.025)	(0.023)	(0.069)
Height-for-age, age 7-8	0.737***	0.755***	0.841***	0.728***
	(0.043)	(0.019)	(0.018)	(0.042)
Parental investment in nutrition, age 11-12	0.091***	0.013	0.025	0.037
	(0.019)	(0.019)	(0.022)	(0.030)
Maternal education	-0.012	0.089***	0.000	0.043
	(0.034)	(0.019)	(0.014)	(0.030)
n	523	786	775	703

Notes: (a) Standard errors in parenthesis. (b) All variables are standardized with mean 0 and variance 1. (c) Classical errors are assumed. (d) All equations control for year of birth and whether the household was located in a rural area when the child aged 7-8. (e) In those equations where height-for-age at 11-12 is a right-hand side variable a dummy to control whether the child has reached puberty is included. (f) Height-for-age at each stage is instrumented by household shocks.

Table 10: Cognitive skill formation during the early childhood period (Young Cohort)

	Peru (1)	India (2)	Vietnam (3)	Ethiopia (4)
Dependent variable: cognitive skills, age 7-8				
Cognitive skills, age 4-5	0.262***	0.238***	0.196***	0.172***
	(0.038)	(0.033)	(0.040)	(0.021)
Height-for-age, age 4-5	0.087***	0.148***	0.108***	0.115***
	(0.021)	(0.029)	(0.030)	(0.025)
Parental investment in skills, age 7-8	0.211***	0.092**	0.107**	0.244***
	(0.029)	(0.040)	(0.053)	(0.044)
Maternal education	0.236***	0.253***	0.274***	0.093***
	(0.031)	(0.031)	(0.035)	(0.019)
Dependent variable: height-for-age, age 7-8				
Cognitive skills, age 4-5	0.034*	-0.037	0.056**	0.065**
	(0.020)	(0.024)	(0.026)	(0.030)
Height-for-age, age 4-5	0.753***	0.732***	0.793***	0.645***
	(0.020)	(0.027)	(0.055)	(0.034)
Parental investment in nutrition, age 7-8	0.030**	0.004	0.014	0.047**
	(0.014)	(0.022)	(0.018)	(0.022)
Maternal education	0.063***	0.091***	0.013	-0.012
	(0.019)	(0.017)	(0.022)	(0.025)
Dependent variable: cognitive skills, age 4-5				
Height-for-age, age 1-2	0.089***	0.155***	0.094***	0.098**
	(0.033)	(0.027)	(0.036)	(0.036)
Parental investment in skills, age 4-5	0.085**	0.063**	0.068	0.085***
	(0.041)	(0.028)	(0.055)	(0.021)
Maternal education	0.317***	0.334***	0.238***	0.282***
	(0.039)	(0.033)	(0.059)	(0.054)
Dependent variable: height-for-age, age 4-5				
Height-for-age, age 1-2	0.509***	0.509***	0.633***	0.401***
	(0.031)	(0.034)	(0.028)	(0.049)
Parental investment in nutrition, age 4-5	0.082***	0.063***	0.066**	0.006
	(0.023)	(0.021)	(0.027)	(0.025)
Maternal education	0.161***	0.075***	0.102***	0.088**
	(0.031)	(0.025)	(0.025)	(0.043)
n	1633	1688	1367	1432

Notes: (a) Standard errors in parenthesis. (b) All variables are standardized with mean 0 and variance 1. (c) Classical errors are assumed. (d) All equations control for year of birth and whether the household was located in a rural area when the child aged 1-2. (e) In those equations where height-for-age at 1-2 is a right-hand side variable, the age of the child in months at 1-2 is included as a control.(f) Height-for-age at each stage is instrumented by household shocks and birth size.

Table 11: Testing complementarities in the skills formation model (Older Cohort)

	Dependent variable: Cognitive skills at 14-15			Dependent variable: Non-cognitive skills at 14-15		
	Coeff.	Std. error	p-value	Coeff.	Std. error	p-value
Pooled sample						
Cognitive skills, age 11-12	0.558	0.027	0.000	0.140	0.027	0.000
Non-cognitive skills, age 11-12	0.114	0.017	0.000	0.027	0.017	0.106
Cognitive skills x stunting	-0.044	0.021	0.037	0.012	0.026	0.639
Cognitive skills x severe stunting	-0.044	0.019	0.020	0.016	0.028	0.572
Stunting, age 7-8	-0.023	0.015	0.138	0.024	0.021	0.255
Severe stunting, age 7-8	-0.055	0.017	0.001	-0.006	0.018	0.727
Hh. Non-food consumption, age 14-15	0.215	0.028	0.000	0.211	0.038	0.000
Maternal education	0.105	0.025	0.000	0.054	0.024	0.023
Hh. Is located in a rural area	-0.039	0.039	0.312	0.046	0.046	0.323
Peru						
Cognitive skills, age 11-12	0.564	0.030	0.000	0.202	0.055	0.000
Non-cognitive skills, age 11-12	0.142	0.035	0.000	0.077	0.047	0.099
Cognitive skills x stunting	0.017	0.040	0.673	-0.065	0.054	0.224
Cognitive skills x severe stunting	-0.053	0.060	0.373	0.062	0.053	0.244
Stunting, age 7-8	-0.011	0.023	0.641	0.063	0.047	0.183
Severe stunting, age 7-8	-0.079	0.031	0.011	-0.020	0.037	0.593
Hh. Non-food consumption, age 14-15	0.123	0.019	0.000	0.146	0.051	0.004
Maternal education	0.102	0.032	0.001	0.061	0.044	0.159
Hh. Is located in a rural area	-0.085	0.040	0.033	0.016	0.044	0.718
India						
Cognitive skills, age 11-12	0.591	0.046	0.000	0.277	0.045	0.000
Non-cognitive skills, age 11-12	0.087	0.022	0.000	-0.021	0.030	0.473
Cognitive skills x stunting	-0.060	0.031	0.055	-0.040	0.057	0.483
Cognitive skills x severe stunting	0.024	0.024	0.318	0.002	0.033	0.954
Stunting, age 7-8	-0.020	0.024	0.410	-0.018	0.029	0.524
Severe stunting, age 7-8	0.001	0.027	0.981	0.007	0.023	0.754
Hh. Non-food consumption, age 14-15	0.172	0.044	0.000	0.038	0.044	0.383
Maternal education	0.131	0.034	0.000	0.053	0.032	0.094
Hh. Is located in a rural area	0.086	0.053	0.101	-0.058	0.064	0.362
Vietnam						
Cognitive skills, age 11-12	0.481	0.066	0.000	0.016	0.056	0.773
Non-cognitive skills, age 11-12	0.057	0.026	0.032	0.089	0.038	0.018
Cognitive skills x stunting	-0.026	0.043	0.545	0.080	0.040	0.046
Cognitive skills x severe stunting	-0.125	0.036	0.001	-0.007	0.059	0.900
Stunting, age 7-8	-0.061	0.031	0.051	0.061	0.031	0.052
Severe stunting, age 7-8	-0.147	0.030	0.000	-0.037	0.032	0.250
Hh. Non-food consumption, age 14-15	0.239	0.030	0.000	0.266	0.044	0.000
Maternal education	0.062	0.040	0.123	0.014	0.037	0.708
Hh. Is located in a rural area	-0.028	0.102	0.784	0.120	0.078	0.126
Ethiopia						
Cognitive skills, age 11-12	0.509	0.044	0.000	-0.024	0.053	0.646
Non-cognitive skills, age 11-12	0.053	0.031	0.084	0.051	0.038	0.180
Cognitive skills x stunting	-0.037	0.036	0.309	0.113	0.061	0.065
Cognitive skills x severe stunting	-0.063	0.025	0.011	-0.010	0.042	0.804
Stunting, age 7-8	-0.009	0.037	0.803	-0.025	0.054	0.644
Severe stunting, age 7-8	-0.090	0.035	0.011	0.060	0.056	0.280
Hh. Non-food consumption, age 14-15	0.113	0.046	0.013	0.110	0.065	0.088
Maternal education	0.000	0.044	0.992	-0.053	0.065	0.414
Hh. Is located in a rural area	-0.200	0.067	0.003	-0.052	0.138	0.706

Notes: Classical errors are assumed.

Figure 1: Distribution of cognitive skills by country

Figure 2: Distribution of non-cognitive skills by country (version 1)

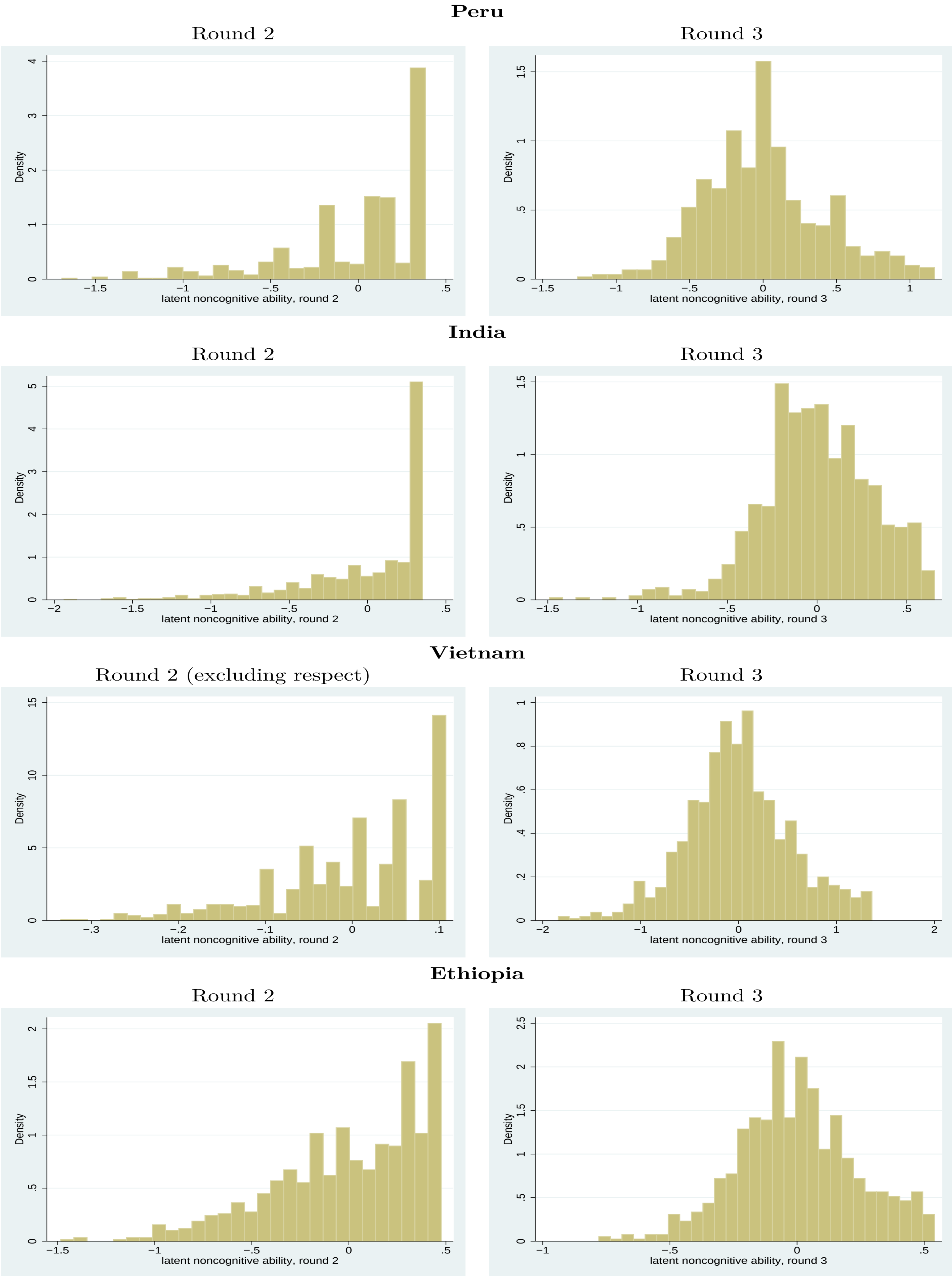


Figure 3: Distribution of height-for-age by country (Older Cohort)

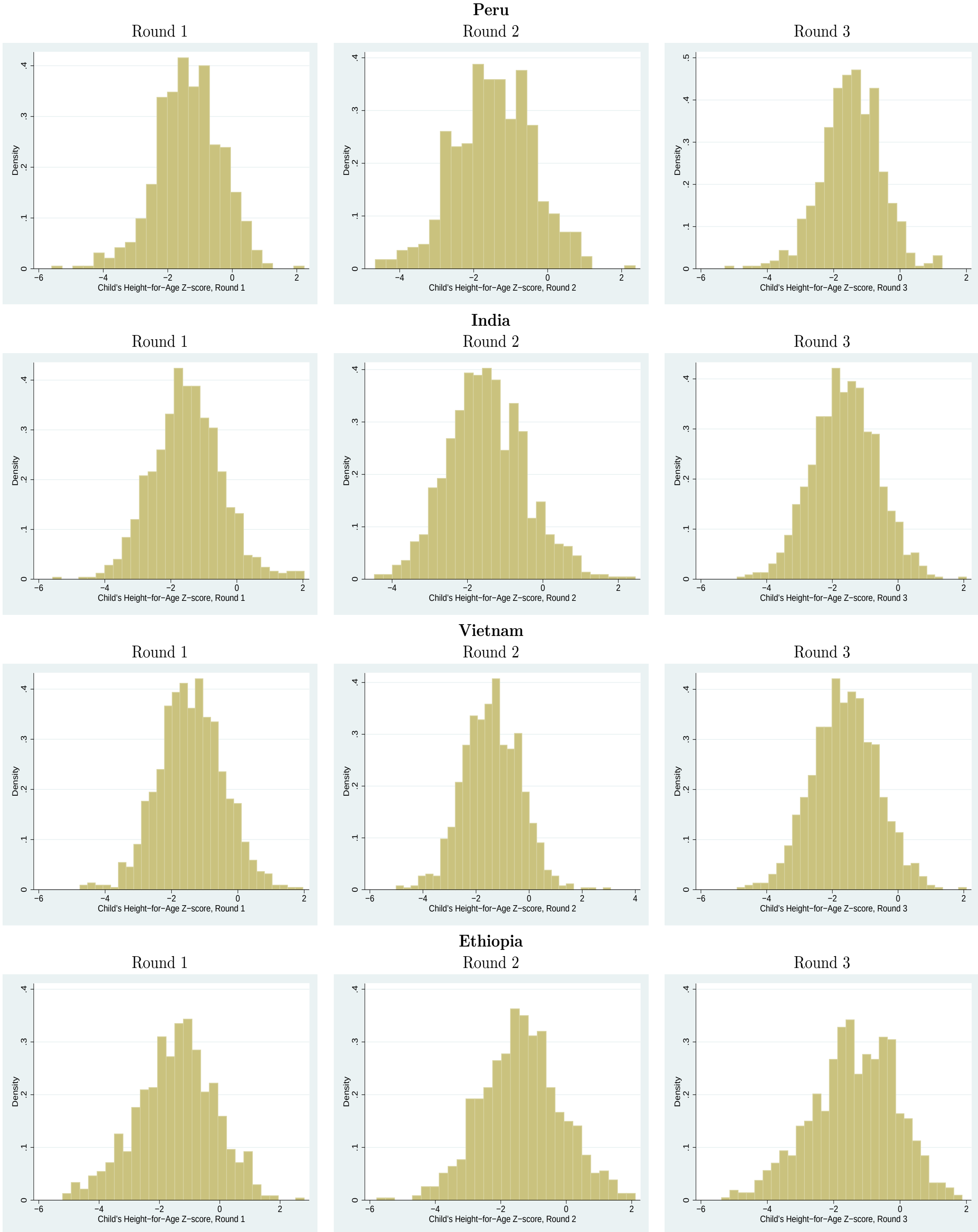
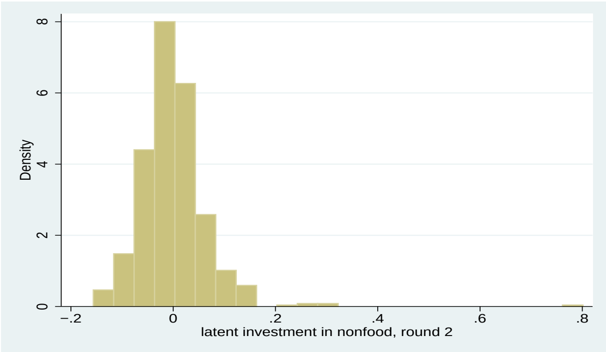


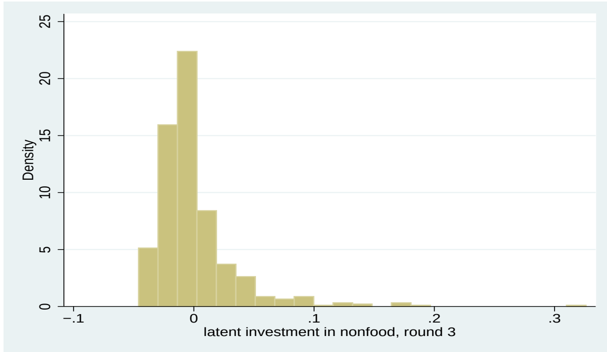
Figure 4: Distribution of latent parental investment in skills by country (Older Cohort)

Peru

Round 2

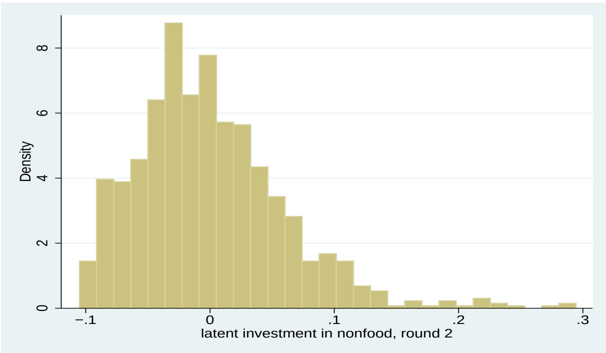


Round 3

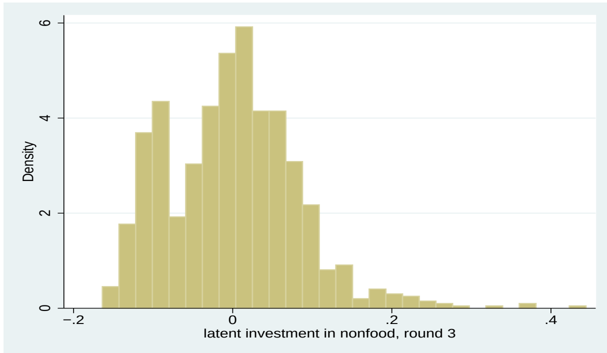


India

Round 2

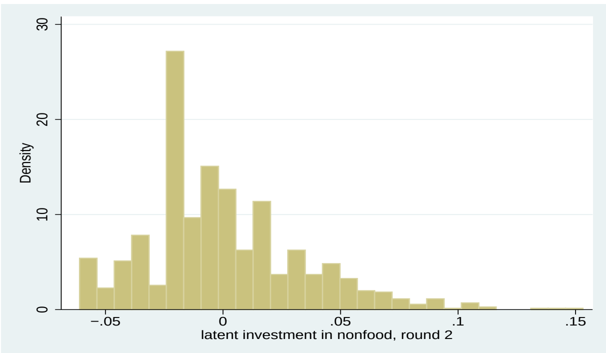


Round 3



Vietnam

Round 2



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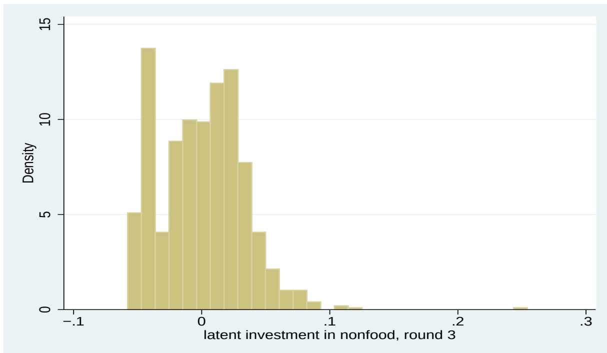
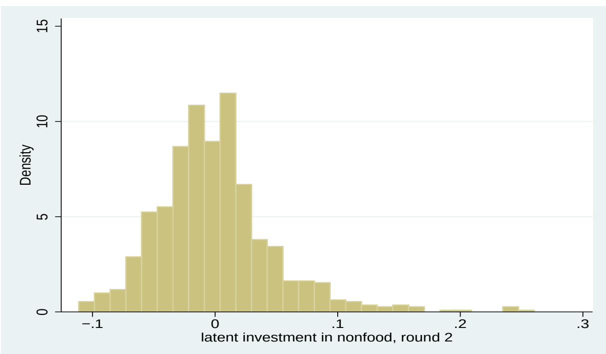


Ethiopia

Round 2



Round 3

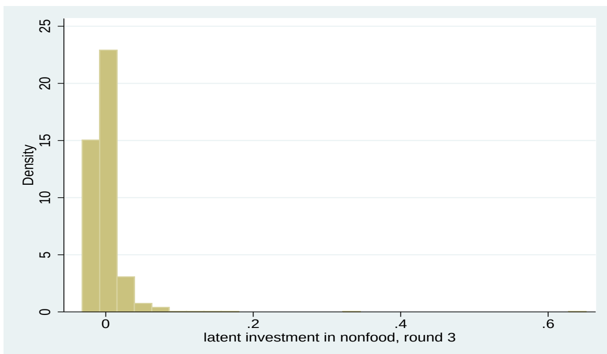
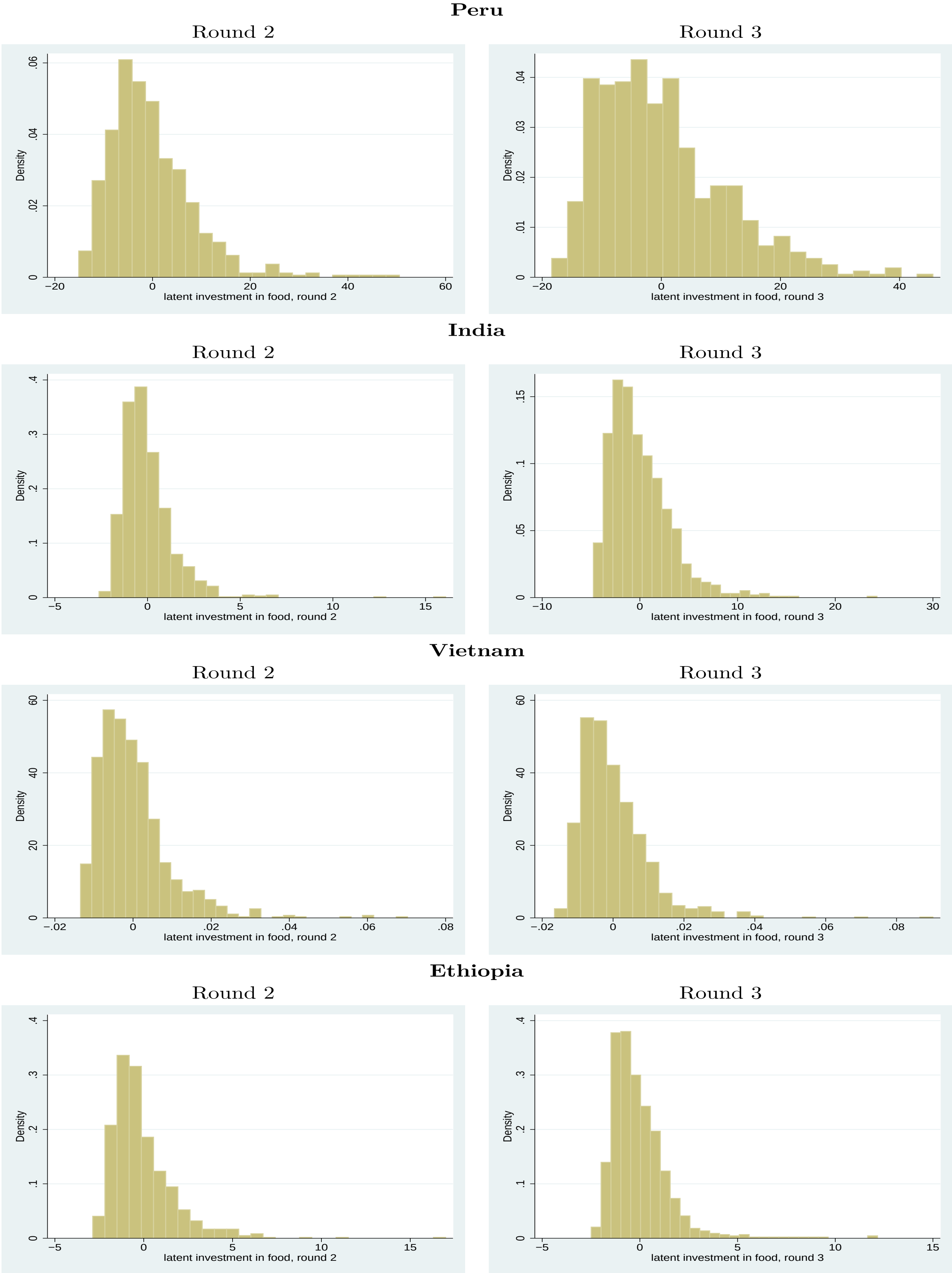


Figure 5: Distribution of latent parental investment in nutrition by country (Older Cohort)



The Structural Relationship between Nutrition, Cognitive and Non-cognitive Skills: Evidence from four developing countries

Both cognitive and non-cognitive skills are rewarded in the labour market. However there is little evidence about how these abilities are formed in the context of developing countries. I study the way in which cognitive and non-cognitive skills are simultaneously acquired in the transition from childhood to adolescence using longitudinal data from four countries: Peru, India, Vietnam and Ethiopia. I estimate a linearized version of the technology of skills formation, linking inputs observed at 7 to 8 years to outputs observed at 11 to 12 and 14 to 15 years. I find evidence of self-productivity mainly for cognitive skills and cross-productivity for both types of skills. I then extend the technology of skills formation to account for the role of nutritional status in the acquisition of skills. Height-for-age is found to be a relevant input in the skills formation model, having a direct as well as an indirect effect on skills accumulation. To obtain estimates of the long-term impact of nutritional investments during the early childhood period on later abilities, I use evidence gathered from a second model that links early height-for-age to cognitive ability at 7 to 8 years. Linking results from both models, I find that an increase of 1 standard deviation in early height-for-age tends to increase cognitive skills during adolescence by 6%, 9%, 17% and 7% in Peru, India, Vietnam and Ethiopia, respectively. It also increases non-cognitive skills by 2% and 4% in India and Vietnam, respectively.

Young Lives
An International Study of Childhood Poverty

About Young Lives

Young Lives is an international study of childhood poverty, involving 12,000 children in 4 countries over 15 years. It is led by a team in the Department of International Development at the University of Oxford in association with research and policy partners in the 4 study countries: Ethiopia, India, Peru and Vietnam.

Through researching different aspects of children's lives, we seek to improve policies and programmes for children.

Young Lives Partners

Young Lives is coordinated by a small team based at the University of Oxford, led by Professor Jo Boyden.

- *Ethiopian Development Research Institute, Ethiopia*
- *Pankhurst Development Research and Consulting plc*
- *Save the Children (Ethiopia programme)*
- *Centre for Economic and Social Sciences, Andhra Pradesh, India*
- *Save the Children India*
- *Sri Padmavathi Mahila Visvavidyalayam (Women's University), Andhra Pradesh, India*
- *Grupo de Análisis para el Desarollo (GRADE), Peru*
- *Instituto de Investigación Nutricional, Peru*
- *Centre for Analysis and Forecasting, Vietnamese Academy of Social Sciences, Vietnam*
- *General Statistics Office, Vietnam*
- *University of Oxford, UK*

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