FORMATION OF COGNITIVE ABILITIES IN MEXICAN CHILDREN: An Empirical Approach[1]

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ABSTRACT

Building human capital is a highly complex process because it involves the convergence of both cognitive and non-cognitive skills. However, the formation of cognitive skills is already a great challenge since the attempt to measure them, and, even more so, when explaining the mechanics of production of these skills in the early years of life. This study uses the longitudinal information provided by the National Survey of Households Living Standards to evaluate the effect of individual, family and community variables in developing short-term cognitive abilities for Mexican children. Our empirical study confirms the importance of self-productivity and family background for Mexico. Additionally, environmental variables are also associated with the abilities formation process. We consider that these findings may constitute a good point of departure for public policy design.

I. Introduction

Since half a century ago, there is consensus among economists about the importance of human capital formation as source of economic growth. The specialized knowledge and skills of people are now recognized as the most important factors in the productivity of modern economies. Synthesized in Aghion and Howitt[2]; models such as Nelson and Phelps (1966), Romer (1990), Mankiw, Romer and Weil (1992), and later, Benhabib and Spiegel[3] (1994), inspired by theoretical developments of Gary Becker (1962) and Theodore Schultz (1961), described the growth as a function of the stock of human capital through increased capacity for innovation and development of new technologies in a given country. In the Lucas[4] model case (1988), the rate of economic growth depends on the rate of accumulation of human capital and not on the "stock". This generates a positive rate of growth in the long run.

Despite the considerable progress that economics of growth have had in recent decades, the relationship between human capital and economic growth is neither obvious nor immediate. Neither clear is the relationship between growth and distribution of its wealth among population. One of the main problems is the measurement of human capital, given its unobservable nature. This compels the researcher to use proxy variables, but also taking into account possible implicit measurement errors.

Since the seminal work of Barro (1991), multiple studies have used school years as indicative of the level of accumulation and/or formation of human capital. Recently, authors such as Hanushek and Kimko (2000), and Heckman, Stixrud, and Urzua (2006), have indicated that the number of school years has not proven to be a variable sensitive enough to explain the long-term economic growth, neither the capacity of individuals to generate additional productivity. Hanushek and Woessmann (2007) showed that the number of years of schooling does not guarantee better economic conditions. Moreover, international evidence shows that long-term economic growth is significantly associated with cognitive abilities of individuals, which are determined by multiple factors including the quality of education. In the same sense, these authors have proposed to focus on cognitive and non-cognitive[5]

[2] Aghion, Philipe & Howitt, Peter. "THE ECONOMICS OF GROWTH". The MIT Press, 2009. Pg. 287
[3] Op. Cit.
[4] Op. Cit.
[5] Non-cognitive ability is related to other dimensions of individual behavior that plays an important role in the success or failing of the individual in life. Such dimensions are: motivation, ability to work with others, concentration, discipline, self-esteem, level of impatience, mental health status, etc.

abilities of individuals, as components of human capital accumulation (Cunha and Heckman, 2006; Cunha and Heckman, 2007; Heckman, 2008; Hanushek and Woessmann, 2007).

In such studies, the cognitive ability is a multidimensional factor whose several determinants are positively correlated. In general, the concept of cognitive ability refers to the individual's capacity to quickly understand new concepts, to solve problems which has no familiarity with, and to see relationships that others cannot see. (Dickens, 2007)

Goldin and Katz (2008) have argued that an explanatory element of growing inequality in the United States is the distribution of cognitive ability among individuals to adapt to new technologies and become more productive. To the extent they are able to assimilate new technology requirements, they may participate in the benefits that come with productivity growth, otherwise would be left behind.

But not only individual income, income distribution and economic growth are related to cognitive abilities. Heckman (2008) and Borghans, et al. (2008) summarize a significant body of studies which show that: work experience, school performance, participation in risky activities, teenage pregnancy, and health outcomes are strongly affected by cognitive and non-cognitive abilities.

If such skills are important components of what is called "human capital", is then pertinent to ask how to measure these skills, being, as mentioned above, latent variables that are not directly observable. Consequently, questions also arise about their determinants, about the stages of the life cycle of individual when the skills are formed, as well as, the highlights for the design of public policies that promote their development.

Formerly, the cognitive abilities of the individual were assumed to be determined mainly by genetics as Herrnstein and Murray (1994) pointed out in their influential work: *The Bell Curve.* However, a comprehensive survey of evidence (Feldman, Otto and Christiansen, 2000; Todd and Wolpin, 2006; Heckman, 2008) show that genetics play a more tangential role in cognitive formation than it was previously thought. They highlight the importance of other factors like: cultural patterns, family background, physical and mental health of the individual, the level and quality of education received, and the community environment, in the formation of cognitive abilities and its distribution among population. Moreover, there is evidence that interventions in the early years of the life are crucial in the development of these skills. This point is critical, in order to attend the inequality conditions generated by the mere "accident of birth" as Heckman stated.

Actually, there is vast economic literature that analyzes the relationship between economic outcomes and cognitive skills accumulation, as well as, its association with economic performance and social mobility of individuals throughout their life cycle. However, despite the importance of the issue for the formulation of public policies, in Mexico there are few studies that explore these relationships. One of the limitations has been the lack of reliable and comprehensive data that allows testing the short and long-term hypotheses. Until recently, Mexico began to generate information about educational achievement through test scores such as PISA,[6] which is applied at international level, or test ENLACE[7] that is applied each year in Mexico. Despite this information is important to measure the educational performance of students, is not possible to complement it with additional information from other characteristics of individuals and their context, in order to shape the process of skills accumulation.

The Mexican Family Life Survey (MXFLS) is the only source of information that contains data about cognitive ability of children and adults that can also be linked with a vast pool of socio-economic characteristics at individual, household, and community levels. Most of the analysis based on this source of information are cross-sectional, some of which have focused on testing the hypothesis of intergenerational transmission of cognitive skills (Ruvalcaba and Teruel, 2004, Mayer, and Servan, 2008; Altamirano, et al., 2009); or the association between child and family abilities with institutional and community environments (Mayer and Servan, 2009). Recently, Hincapie and Soloaga (2010) took advantage of the longitudinal nature of the survey to conduct an analysis of formation of child cognitive ability following the theoretical model proposed by Cunha and Heckman (2007).

The objective of this study is to estimate the contribution of individual, family and community characteristics in the evolution of short-term child cognitive ability. Additionally, the study seeks to assess the weight of each of these factors in the formation of cognitive skills depending on age range and social status.

The paper is organized as follows: the section II briefly describes the theoretical model that support the empirical specification; the section III describes in detail the data source and some of the descriptive results of the survey; the section IV presents the main results of the estimates; and finally, the section V addresses the conclusions and limitations of the study, as well as, policy recommendations.

[6] PISA is an OECD Program for International Student Assessment.
[7] ENLACE: Evaluación Nacional del Logro Académico en Centros Escolares

II. *Theoretical approach*

The theoretical approach builds upon the one developed by Cunha & Heckman (2007). The model summarizes findings on psychology, education, and neuroscience in the capabilities formation, and also states that cognitive and non cognitive skills formation occurs in an evolutionary process whose stages along time, are positively influenced by a combination of factors involved with different intensity at each stage of childhood. The production function of cognitive and non cognitive skills takes the following form:

$$\theta_{t+1} = f_t(\theta_t, I_t, h, z, \mu_t) \quad \ldots\ldots(1)$$

Where, I_t denotes parental investment in child at t; h denote parental capabilities like genes, cognitive skills, education, income, etc; and z brings together the characteristics of the environment in which the child develops. At each stage t, θ denote the vector of stock of skills or capabilities as function of past investment and the endowment of skills. Substituting θ_t by θ_{t-1} and so on, we can rewrite the equation (1) as follow:

$$\theta_{t+1} = f_t(\theta_1, I_{1\ldots\ldots} I_t, h, z, \mu_t) \ldots\ldots..(2)$$

It is assumed that the function is strictly increasing and strictly concave in I_t $(\partial f_t / \partial I_t > 0)$ and twice continuously differentiable in all its terms, i.e., more investment produce more skills.

The "differentiability" assumed in the production function, is the property that allows adopting the concepts proposed by Heckman, which he calls "*self-productivity*" and "*dynamic complementarity*"

The former can be expressed as:

$$\frac{\partial f_t(\theta_t, I_t, h, z)}{\partial \theta_t} > 0$$

This means that the stock of capabilities has a cumulative property, allowing former skills to influence positively in later periods. A large background of skills at t allows the creation of a bigger one at $t+1$.

On the other hand, dynamic complementarity is expressed as:

$$\frac{\delta^2 f_t(\theta_t, I_t, h, z, \mu)}{\delta \theta_t \delta I_t} > 0$$

This means that skills acquired in period t make investment I_t more productive. In other words, child with higher initial skills respond more effectively to early investments. In Heckman's words, this property of complementarity explains why returns to education are higher in those persons who developed higher skills at early stages of life. Moreover, is necessary to distinguish the relevant periods of skills formation, which can be classified as critical and sensitive. The *critical* stages are determined by comparison, where the investment is productive in a certain period but not in another. On the other hand, the sensitive periods are those that distinguish the intensity of the effect. Thus, under the same level of inputs, investment is more productive at one stage than another.

The technology represented in (2) allows us to estimate the accumulation of skills throughout the life cycle of the individual, and also capture the multiple periods that empirical evidence proves to be critical or sensitive for intellectual development during childhood. Heckman points out that even the preconception and in-utero stages, may be important in the development process and can be incorporated into the production technology.

A comprehensive approach to this technology claims a long-run following of individuals, in order to identify the multi-stages of development and distinguish between investments made in early ages of those made in later ones. For purposes of policy design, it is very important to know the degree of substitutability or complementarity between investments, i.e., to what extent it is possible to remedy what was not done in the past. If the investments were high level complements, investment in the early stages of life are crucial. On the other hand, if they were substitutes, the remediation always is possible.

Cunha and Heckman (2007), Cunha, Heckman, and Schennach (2010), provide evidence claiming that childhood remediation is possible but, decreases with age. The most effective interventions are those that occur in the early stages of life. The same authors (Cunha and Heckman, 2010), explain that in some cases of adults and even young people is not always efficient to invest in their skills. In the case of adults with major disadvantages is better to offer them subsidies or social protection schemes instead of investing in the upgrade of their skills. Furthermore, given the heterogeneity in endowments, it would not be appropriate to implement a universal program that seeks to remedy the disadvantages that come from childhood.

III. Empirical approach

The empirical specification of equation (2) is challenging due to the latent nature of θ and I, and the lack of data to model complete life stories. Notwithstanding, it is possible to use a restricted model

with only two points at the time. In its basic form, the *added value* specification states an achievement outcome θ_t as a function of contemporaneous household and context inputs, and to a lagged outcome of interest θ_{t-1} (Todd and Wolpin, 2005). Assuming that the production function is approximately linear in their arguments, the empirical specification has the form:

$$\theta_{ij,t+1} = \beta_1\theta_{ij,t} + X_{ij,t}\beta_x + I_{j,t}\beta_i + h_{j,t}\beta_h + z_{k,t}\beta_z + \varepsilon_{i,j,t} \ldots\ldots(3)$$

Where θ_t and its lag θ_{t-1} represent the cognitive ability of children, which is a latent variable, approximated in this analysis by the Raven's score test; X_{ijt} denotes all those characteristics of the child, as: age and gender. The parental variables are contained in h_{jt}, which include: the Raven´s score test of the mother (or guardian), age, education, and the belonging or not, to an indigenous group.

While it is not possible to identify all of the investments (*I*) on the child in past stages, it is possible to approximate it through their achievements in *t*. For this the analysis, we included variables such as: whether the child attends school; if she gets help for homework, and if receives PROGRESA[8] (now called *Oportunidades* program) scholarship. It was also included demographic variables related to household, assuming that the presence of other children and adults modify investment decisions.

It should be noted that parental information belongs only to the mother or guardian of the child, given that variables related to father presented serious problems of missing data. On their side, variables z_j denote the community environment in which the child develops, and are identified in this analysis using two indicators: the existence of a library in the locality, and the proportion of schools in the locality with computers for student use.

In order to obtain efficient and consistent estimators, the model was estimated by linear OLS with robust standard errors for heteroskedasticity and clustering correlation. The estimation assumes exogeneity of regressors. The argument supporting this assumption is that the production function depends on inputs that are beyond the control of children, including parental and household characteristics, or context variables. Even in the case of behavioral variables such as attending school, those are decisions made by parents in a dictatorial way. The estimation of equation (3) was made for sample of children from 5 to 12 years old at baseline (2002) and who were also interviewed in t+1 (2005).

[8] PROGRESA is a Conditional Cash Transfer program that focuses its actions in households with higher levels of poverty. PROGRESA's beneficiaries receive a package of benefits related to health, education, and nutrition. In return, the household must meet a number of co-responsabilities

Economic literature has traditionally shaped the formation of cognitive skills during childhood as time homogeneous in the life cycle, however, (as pointed recently by psychology and taken up by developmental economics) in child's cognitive formation there are critical periods where improvement of certain types of skills becomes more sensitive. There are skills that cannot be learned before certain age and others that are more difficult to be acquired later in life, such as mastering a second language as native, as noted by Heckman (2008). These findings undoubtedly have important implications for public policy design.

While economic literature about cognitive abilities is under construction and there are no conclusive results yet, the few studies conducted, suggest that interventions with higher yields are those that occur during early childhood. By the dynamic complementarity property is that the production of skills in a life cycle period increases productivity of investment in the next. Without attempting to test fully this hypothesis, but with the intention to identify heterogeneous effect on θ_{t+1} for different age strata, a regression model was adjusted for the younger children group (from 5 to 7 years old in 2002), and another for older children (from 8 to 12 years old).

A second strategy of analysis was to estimate equation (3) for each quintile of household expenditure. The objective was to inform whether the proposed technology operates similarly to different socioeconomic levels, not only in terms of the effect of each input, but also whether the weight of the omitted variables is the same. This analysis is particularly important for policy formulation; additionally it is important to discover if an intervention designed to improve cognitive abilities of children has to be differential or should be universal. Finally, the model was estimated separately for the sub-samples of children living in rural areas, semi-urban areas from 2,500 to 100,000 inhabitants, and urban population over 100,000 inhabitants.

IV. Information Source.

The empirical estimation uses as source of information the Mexican Family Life Survey (MXFLS). The MXFLS is a longitudinal, observational and multi-thematic survey. Its goal is to provide information about dynamics of living conditions of the Mexican population. Baseline information was collected in 2002 and the first follow-up panel in 2005. The survey provides comprehensive information on various aspects on living conditions, such as educational level, conditions of health, employment, income and expenditure, migration, and other socio-demographic characteristics. In addition, children between 5 and 12 years of age, and household members from 12 to 65 years old, were applied a test of cognitive abilities through the Raven's Progressive Matrices test.

Raven tests are designed to measure cognitive ability of the person without requiring that it can read or write. The children's test is formed of 18 colored progressive matrices, and applied to children aged from 5 to 12 years at home. The survey also provided the correct answer for each Raven's matrices of which, a simple summation of right answers gives a good estimate of cognitive ability of individuals at solving this type of examination. Test for members over 12 years of age was composed of 12 progressive matrices using the same logic applied to those used for children.

The basic assumption at explaining the formation and evolution of cognitive skills is that the Raven's tests, both in its standard version (in the case of adults) and in colored version (in the case of children), is a reliable measurement of cognitive ability to perform tasks of abstract reasoning, because they were designed to measure the skills to build relationships by analogy, regardless of language and education.

The survey sample's design was probabilistic, stratified, multi-staged and independent in each domain of study, where the last unit of observation was the household. The primary sampling units were selected under a pre-established criterion of national representation, urban-rural, and regional, of demographic and economic variables (INEGI, 2004). The sample size from baseline survey is 8,440 households and about 38,000 individual interviews. The first panel of the survey was built in 2005 and 2006 with re-contact rates of around 90% at household level. The effort to follow migrating members produced a re-contact rate close to 91%. The information on general characteristics of the community was collected in the 150 localities from the baseline sample.

Household information was provided by an adult member, while the individual information was obtained directly from the individuals selected. Additionally, information about level pricing, infrastructure, health and education providers, as well as other features at the locality level were also captured in the MXFLS. More details on the survey are on Ruvalcaba and Teruel (2004).

The sample for analysis was formed of children from 5 to 12 years who completed the Raven's test in 2002, and were re-contacted for the same test in 2005. To test the hypothesis in the theoretical model it is required at least, to have information at two points in time. Of the 5,864 children who completed the test in 2002 only 2,884 children were applied the same test in 2005[9]. In order to ensure the comparability of the answers, it was only taken into account the test designed for children (test of

[9] There were not included in the sample 238 children residing in Sonora state, given that estimates showed an atypical result of these children with respect to the rest of states. Subject to investigate the causes of this result, it was decided for this analysis to exclude this sub-sample data.

18 colored matrices) in both rounds, that is, it was not took into account the information of children who in 2005 answered the test for adult members because of their age.

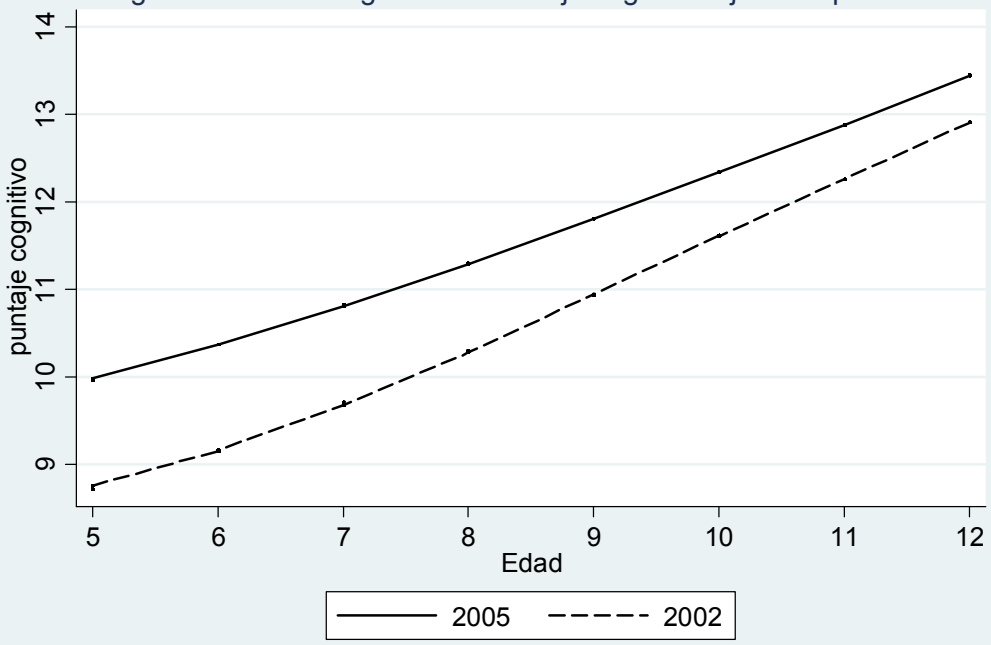
Total household expenditure was constructed from the information contained in the book called "Characteristics of house consumption", in which detailed information was gathered on household expenditure on food, personal items and cleaning services in general, culture and recreation, clothing and footwear, spending on education and health services. It was not considered spending on durable goods, vehicles, and those related to parties or vacations. Total estimated expenditure for 2002 and 2005 was deflated to march 2002 prices, in order to express it in constant terms.

To facilitate the presentation of the results, 4 sets of variables were constructed. The first corresponds to characteristics of the child as unit of analysis; the second, to variables associated with investment in the child; the third group refers to parental[10] and household characteristics; and the fourth group has context inputs denoting some variables at locality level.

Distribution of cognitive scores by age, in Figure 1 shows a positive gradient with age of children, which was already expected if we consider that as children develop with age so does their reasoning ability. Interestingly, the marginal rate of growth is constant in the interval of age analyzed. That is, between 5 and 12 years old, on average, the cognitive ability is growing steadily with age.

[10] Parental characteristics correspond to mother or tutor of the child. It is noteworthy that in 93% of cases, the mother is the tutor of the child. However, for not losing sample observations, the mother's information was supplemented with data from the responsible of the child at home. It was not taken into account information from the father because 22.7% of children were not living with him, so the analysis including information on the father implied a sample loss in the same proportion.

Figura 1. Lowess regression. Puntaje cognitivo ajustado por edad



Fuente: ENNVIH 2002 y 2005. Sólo incluye a los niños con información en ambas rondas de la encuesta.

Another interesting feature is that between 2002 and 2005, there was a general increase in cognitive ability for all age-group children, especially in younger ones, resulting in the displacement of the graph up. The graph is constructed by comparing scores in 2002 and 2005 as cross-section analysis, which includes new children who entered to refresh the sample in 2005, without imposing restrictions on the balanced panel.

Figure 2 presents another way to describe the score's differences between the two rounds of the survey. By analyzing the distribution of Raven's score, it shows that the 5th percentile of the distribution reaches six points in 2005 while in 2002 the same percentile had reached four points. For the 50th percentile, the gap narrows to 1 point, while in the upper percentiles (90% and higher) the gap between the two rounds was closer. Note that the gaps are larger in the lower percentiles of the distribution.

When obtaining ratios or relative gaps between the median score and that located in the 10th percentile, the result indicates that the ratio is 1.83 in 2002 and 1.71 in 2005. In relation to the 95th percentile the ratio is 0.687, which increases to 0.75 in 2005, reducing the gap between the two groups. Similarly, the Lorenz curves reveal that the distribution of cognitive ability in the children population is less unequal in 2005 than in 2002 (see Figure A1).

Figure 2. Distribution of child cognitive ability 2002-2005

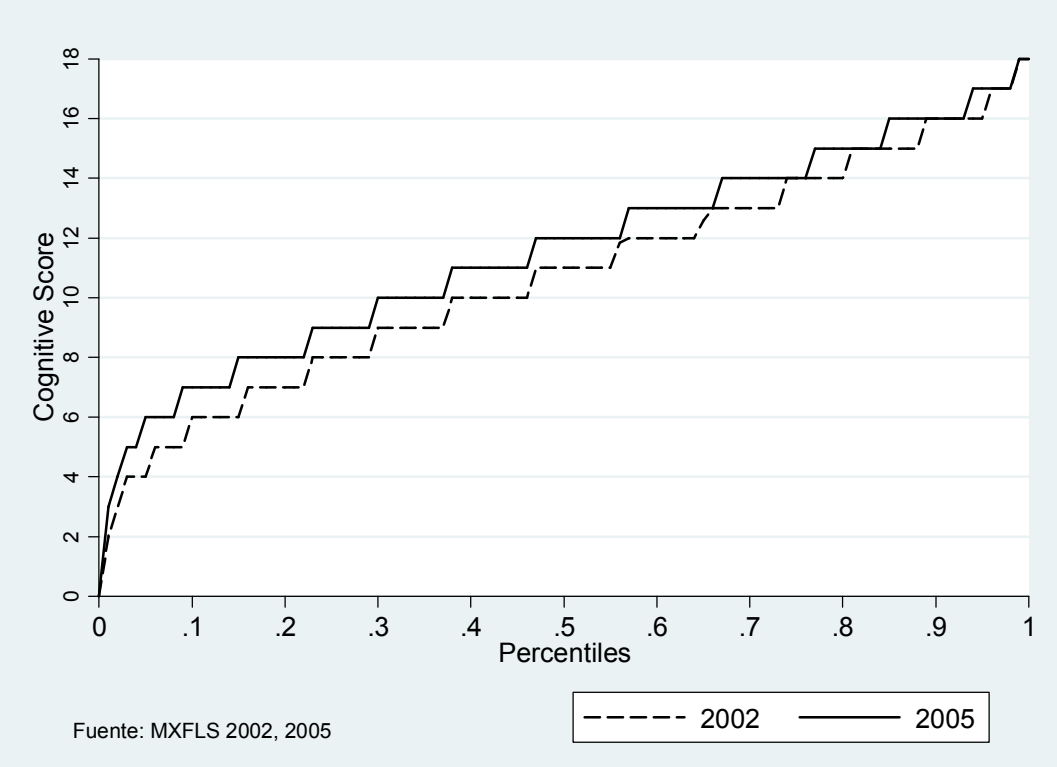


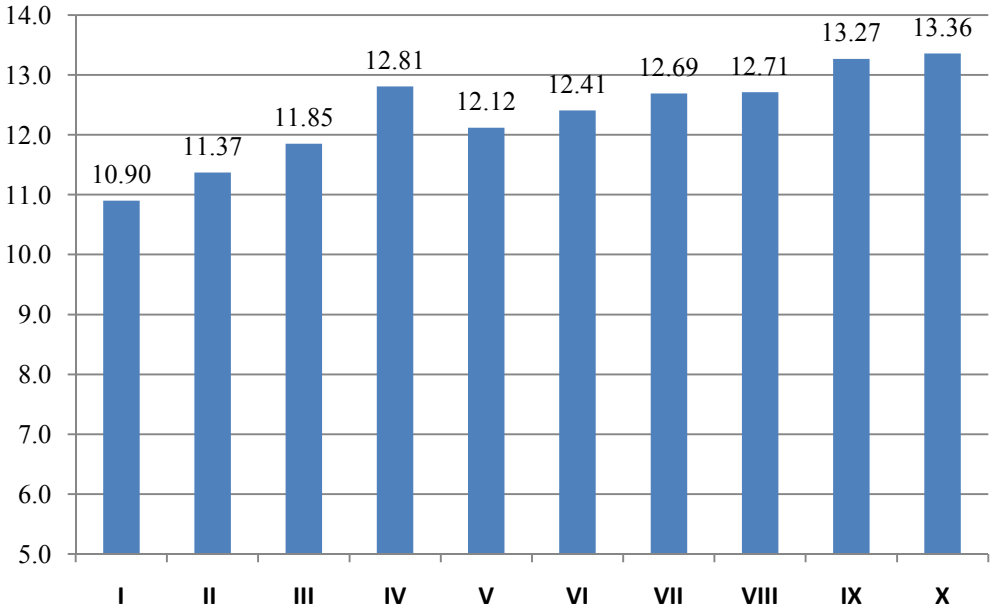
Table A1 (see Annex) shows that the average score on cognitive ability of children at baseline was 10.70 of 18 possible points. For the same round the average for the sample of balanced panel was 9.54 points. This difference explains why the older children in 2002 -with higher scores-, were not considered in the sample for analysis in 2005. The baseline characteristics show that the sample for men and women is evenly balanced; 93% of children were attending school at the time of the survey; 76% lived with both parents; nearly half reported giving help to the child to do homework; and 14% of them received or have ever received PROGRESA scholarship. With regard to the parental and household characteristics, the baseline sample (2002) and the balanced panel are very similar, suggesting that the loss of sample for analysis was not systematically different at household level. The average age of the mother (or guardian) was around 36 years old; about 45.8% had primary level education, and only 17.5% had high school education or more; 17% of the mothers said to belong to an indigenous group, and 60% reported to be engaged in any work activity in the twelve months previous to the survey.

Regarding the local characteristics, baseline information shows that 53% of the localities had a library, and on average 55% of the local schools had computers for student use. By stratifying the

information of 2002 by area of residence, it appears that 46.8% of children reside in rural localities, while 32.9% lived in urban areas of more than 100,000 inhabitants. When analyzing the balanced panel sample, one can observe that sample loss between 2002 and 2005 fell mostly in densely populated urban areas; this is confirmed by checking the average monthly expenditure of households, where the sample of children living in households in the balanced panel is slightly poorer ($4,068 pesos) than the rest of the sample ($4,260 pesos).

One of the most consistent findings in the literature is the relationship between income level and formation of cognitive and non-cognitive skills (Hanushek and Woessman, 2010). As stated above, children born in more affluent families tend to develop more and better skills throughout their life cycle. This allows them to adapt relatively easily to most sophisticated labor markets demands and enjoying thus the benefits that greater specialization brings with. To explore this hypothesis, the specific measurement of inequality is appropriate to clarify the disparity of skills under different grouping criteria such as age, geographic location, town size, household income, etc. Figure 3 confirms what was expected. Children belonging to higher socioeconomic deciles had an average cognitive score higher than children in the lowest ones. The difference was almost 2.4 points in the Raven's test.

Figure 3. Puntaje cognitivo promedio de niños de 5-12 años. Por decil de gasto



Fuente: ENNVIH 2005

Similarly, as shown in Table 1, children living in rural areas were on average the lowest score compared to other population areas, reaching nearly 1 point Raven's test below the average observed in semi-urban areas, and 1.45 points below the urban centers.

Table 1. Puntaje cognitivo promedio de niños de 5-12 años. Por área de residencia.

Rural < 2500	11.69
Semiurbanos 2500-15 mil	12.58
Urbanos 15-100 mil	12.91
Urbanos > 100 mil	13.14

Fuente: ENNVIH 2005

The estimate of the Gini index by state reveals that those with the lowest Raven's average score at baseline, such as: Michoacan, Oaxaca and Puebla, also had the most unequal distributions between its child population among all the states of the sample (see Annex, Table A2). However, by 2005, there was a decrease in the coefficient of Gini for the entire population, particularly in states that had the greatest disadvantages at 2002. On the other hand, states with higher average scores at baseline (DF, Durango and Nuevo Leon), exhibit no distributional changes between the two rounds of the survey. These results suggest that between 2002 and 2005, the gap among those who obtained the highest scores and lowest scores were reduced, not only at national level but also, between and within states.

Additionally, to range measurements to describe the distribution of a variable, Wagstaff A., et al. (1991) proposes the Concentration Index[11] (CI) as a better measure for analyzing inequality in health. The CI reflects not only the behavior of the total population, but also allows for association with socio-economic characteristics such as income level. According to this methodology, the indices and concentration curves of cognitive skills reveal that inequality of cognitive skills (measured by the Raven's test) by income level is not as pronounced for either of the two rounds (see Annex, Figure A2). At baseline, the concentration ratio was 0.066 while in 2005 was 0.027. This result points out that the gap between rich and poor children is not too wide, and that between 2002 and 2005 this gap was reduced.

[11] The concentration index is a measure of inequality analogous to the Gini coefficient, the difference is that the ordering variable is not the same as the variable whose distribution is of interest. Its range is (-1, 1) where the edges denote concentrations in the poorest or richest of the population depending on the indicator in question, the zero indicates a neutral distribution or that there is no inequality.

V. Estimation Results

a. Estimates by age strata

As specified previously, the production function of cognitive skills involves the combination of inputs at individual and parental level with others related to environment. In the case of children, besides the genetic component, the influence with greater degree of immediacy is exercised by parents through a series of investment decisions along the infant's life cycle that seek to maximize their potential development. The investment decisions depend on the material and immaterial resources of the family.

Table A3 presents the OLS estimators of equation (3) for all children and two age-groups. A sub-group was formed by younger children from 5 to 7 years old; the other sub-group was formed by the sample of children from 8 to 12 years old. The estimation of the original Heckman's model which does not include community-level variables is presented in columns 1, 3 and 5; columns 2, 4, and 6 present the results of the full model including variables related to the locality. The estimators of the latter are preferred for this study. For all estimators, the F-tests of joint significance of the community-variables were significant.

For all children sample, the cognitive skill achieved in *t* (observed in 2002) is a strong predictor of cognitive ability in *t +1*, as well as it is age. This finding involves the natural improvement that individuals follow in neuronal capacity to process certain information along age. In line with expectations, the effect of cognitive accumulation in *t* over the level observed in *t +1* is not as large in younger children (column 4) as it is in older children (column 6). The explanation for this result is based on the dynamic complementarity property of cognitive formation technology, which strengthens the hypothesis that cognitive formation of individuals at an early age is self-productive. According to the associated coefficient, for older children the lagged cognitive effect on score in period *t +1* results in an increase of 0.212 Raven's points, when the effect on younger children was only 0.09 points.

The gender variable is not significantly associated with cognitive skills. As predicted by the Heckman's model, investment in education like: school attendance, parental homework help or help to study, or receive the PROGRESA scholarship, has a positive effect on cognitive skills accumulation. The column 2 shows that combination of investment variables increases about 1.42 points the children's cognitive skills measured by Raven's test.

With regard to parental variables, several interesting findings arise. The F-test of joint significance of parental variables is high, indicating that their influence is very important. The results confirm that cognitive skills of infants do not rest entirely on the genetic component as has been found in other studies. As theoretical model states, the parental dimension has an important role on the cognitive development. A child who is educated by a parent with high school education (or higher) has 1.12 Raven's points more than the child educated by parent without schooling. However, returns of schooling would be biased if not including variables that are simultaneously related to mother's schooling and child's cognitive level. To reduce this potential endogeneity bias, it was included the mother's cognitive score observed in 2002. The accumulated cognitive skill of mother or child's guardian has a significant and positive effect on child's cognitive skill, which is around 0.10 Raven's points. It is noteworthy that the largest effect was observed in the group of younger children from 5 to 7 years old, while in the older children this effect loses magnitude and significance. Interestingly, the intellectual development of older children rely more on their own accumulated skills, and less on cognitive influence of the caregiver.

As could be foreseen, belonging to an indigenous group is negatively associated with cognitive score; but, the association is negative only in the older children group (8 to 12 years old). To control for welfare conditions, there were taken into account both household variables such as: demographic composition, income level, and community characteristics.

As has been documented in other studies, the socioeconomic status (measured by monthly real expenditure) is positively associated to cognitive skills formation. For the whole sample, children living in quintile V of expenditure, have Raven scores 0.797 points higher with respect to children in quintile I, showing a significant positive gradient with increasing socio-economic level. The household demographics also matters, and its relationship is negative with skills formation in children. The presence of children under 5 years old in the household is negatively associated with cognitive formation especially for the older children. This result may be due to a substitution effect, where parents tend to reduce investment in older children to engage in the smaller ones. On the other hand, cohabitation with more adults at the household has a positive effect on cognitive development of children, particularly in the smaller children group. This may be because more adults are willing to help the child's development.

An interesting result, not yet explored in other Mexican studies, but very important to policy formulation is, that community context is relevant. Controlling for other variables, children living in

localities with a library, scored higher cognitive abilities. Similarly, children living in areas with a greater number of schools with computers for students use, exhibited higher Raven's scores. It is possible that the effects of these variables are capturing unobserved heterogeneity and by not controlling for it, could cause an over-estimating of the effect of this community property. However, regardless of the transmission mechanism, investment in cultural capital in the community will always have positive effects on population.

The estimates for the full sample and for both age groups show that even when community factors do matter; individual and parental characteristics explain about 93% of the total variance explained by the models, evidencing that children's cognitive formation rely on those belonging to the individual and those associated with parents.

b. Estimates by socioeconomic strata

As was noted above, the economic literature provides a strong association between socioeconomic status and cognitive level of the people. Nonetheless, a relevant question is whether several important factors on cognitive formation have heterogeneous effects depending on the socioeconomic level, or if there are unobserved heterogeneity that could be skewing the results.

Table A4 shows that for all expenditure quintiles, the only consistent finding is that cognitive ability in *t* is significantly associated with the cognitive skill at *t+1*. For other variables the results are ambiguous. Note that the effect of mother's education is higher and significant in lowest socioeconomic quintiles, losing statistical significance in higher quintiles. In the same sense, mother's cognitive skill is important only for children belonging to II, III, and IV quintiles. Regarding community-variables, the OLS results, stratified by quintile, do not produce consistent outcomes; notwithstanding, the coefficients exhibit the expected sign.

Stratified analysis by income level is inconclusive, which claim to be reviewed in greater detail.

c. Estimates by area of residence

The stratified analysis by area of residence (see Table A5 in annex) gives some interesting results. As mentioned above, the cognitive skill accumulated at *t* is the most consistent predictor in formation cognitive at *t+1*. The results in the sub-sample of children living in rural areas show that, in relation with other children, (living in densely populated areas) parental investment variables are significantly associated with cognitive formation. Moreover, it is interesting to note that this is the only

group where PROGRESA scholarship has a significant effect. Remember that the PROGRESA program began in 1998 in rural areas, expanding their benefits to semi-urban areas in 2001, and urban areas in 2002; therefore, children at 7 and 12 years old from rural areas in 2005 possibly received the benefits of nutritional component of PROGRESA since they were infants, and even some of them were beneficiaries of the nutrition and health components while still *in-utero*. This is confirmed by the results presented in Table A3 for the younger children group, where PROGRESA shows the larger effect. However, being part of an indigenous group seems to be a limiting factor for cognitive development in rural areas, which could be capturing a series of lagging conditions that have affected the child's development throughout their cycle life.

With respect to parental and community variables, the results are less clear. It is observed that the effect of cognitive ability of the mother (or guardian) is significant in children from rural areas and cities of more than 100,000 inhabitants. On the other hand, maternal education was significantly associated only with children living in semi-urban areas. An explanation for this phenomenon cannot be provided.

About household socioeconomic variables, only in rural and semi-urban areas, income level seems to be strongly associated with the formation of cognitive ability. In large cities this association is not verified, a possible explanation for this lies in the existence of other environmental circumstances that act as compensating factors. Note that, adjusting for other variables, exposure to a greater number of computers for school use has a highly significant effect on the formation of cognitive skill.

Finally, the OLS estimators reveal that cognitive skills formation in children involves the combination of inputs at individual and parental level with others related to environment. Besides the genetic component, the greater influence is exercised by parents through a series of investment decisions along the infant's life cycle that seek to maximize their potential development.

VI. Final remarks

Building human capital is a process highly complex because it involves convergence of both cognitive and non-cognitive skills. However, formation of the first ones is already a great challenge since the very attempt to measure them, and even more so, to explain the mechanics to operate the various factors of production of these skills in infants.

The econometrical approach of this study confirms the property of self-productivity for the Mexican case. In all estimates, cumulative cognitive ability appears to be a strong predictor of skills in

t+1, and moreover, the effect is greater as children grow up. In the same vein, the obtained results suggest the presence of sensitive periods when clustering by age groups. At early ages, what greatly matters is the stimulation that children receive from their parents and home environment. In particular the mother's education has come to represent large-scale differences in the number of successes achieved in the Progressive Matrices test. As children get older, individual factors become more important, among these, attending school is crucial for an adequate performance.

This analysis confirms that investing in children pays off significantly in the early formation of cognitive abilities. Such investment portfolio may be formed of actions ranging from attendance to school, time spent in extracurricular activities, to implementation of public policies, like Conditional Cash Transfers Programs that promote child development since birth.

In general, findings for the Mexican case also confirm the relevance of parental and socioeconomic level of households in the child cognitive formation. However, in previous studies, one aspect that has not been considered (at least directly), is the importance of the environmental variable, particularly, the existence of libraries in the community where the child lives.

The results shows that infrastructure elements related to cultural capital in the community are positively and significantly associated with cognitive development of infants; especially those related to the learning process, such as the mentioned access to a library or to computers at school.

The relevance of this study resides in the fact that it is thought to contribute to the delineation of more effective public policies, in order to improve intellectual development for Mexican children. Now, it is clear that those policies should not only focus on individual aspects, but also may encourage greater parental involvement in children's performance.

In the authorities' arena, public strategies should be concentrated in the improvement of educational quality in every school of the country. To sum up, we consider that the reported findings may constitute in the near future a good point of departure for public policy design.

Unfortunately, the main limitation of the study is posed on the information. To the extent that the longitudinal observation window becomes wider, it will be possible to test comprehensively the implicit hypotheses contained in the theoretical model, but specifically those concerning to the identification of sensitive periods of intellectual development and dynamic complementarity.

However, it is expected that the publication of data obtained in the third round of the MXFLS, will refine the findings raised here and open new horizons to technical study in order to define more effective strategies for infants improvement, and especially for those whose circumstances place them at a disadvantage departure in the cognitive field, but whose future must be, by natural right, just as promising as for any child around the world.

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Annex

Table A1. Estadísticas Descriptivas

	2002 (basal)		Panel (2002-2005)	
	Media	Std. Dev.	Media	Std. Dev.
Características del niño				
n	5,864		2,884	
Puntaje cognitivo (2002)	10.70	3.79	9.54	3.63
Puntaje cognitivo (2005)			12.33	3.31
edad (2002)	8.61	2.26	7.02	1.43
edad (2005)			10.21	1.38
sexo (hombre)	0.50		0.50	
Asistencia a la escuela (2002)	0.93		0.91	
Recibe ayuda de sus padres para hacer tareas	0.55		0.58	
Recibe o ha recibido alguna vez beca PROGRESA	0.14		0.07	
Residencia parental				
No vive con sus padres	4.89		4.40	
Vive con un padre	18.45		17.93	
Vive con ambos padres	76.65		77.67	
Características de la madre o tutor (2002)				
Puntaje cognitivo	5.43	2.93	5.13	2.85
Edad	36.29	12.22	35.58	12.08
Escolaridad				
Sin instrucción	10.45		10.12	
Primaria	45.89		45.62	
Secundaria	25.74		26.72	
Media o superior	17.92		17.54	
Actividad laboral últimos 12 meses	0.60		0.59	
Indígena	0.17		0.18	
Características del hogar (2002)				
Gasto real total mensual	4,260.4	3,552.5	4,068.0	3,425.2
Tamaño	5.87	2.05	5.87	2.07
HH con niño menor a 5 años	0.56		0.64	
HH con adulto mayor a 65 años	0.10		0.11	
Características de la localidad (2002)				
Existe biblioteca en la localidad	0.53		0.52	
Escuelas de la localidad con computadoras p/alumnos	0.55		0.54	
Urbanos > 100 mil	32.95		30.31	
Urbanos 15-100 mil	8.73		8.50	
Semiurbanos 2500-15 mil	11.49		11.17	
Rural < 2500	46.83		50.03	

Fuente: MFLS, 2002, 2005

Figure A1. Lorenz curves in Raven's cognitive score.

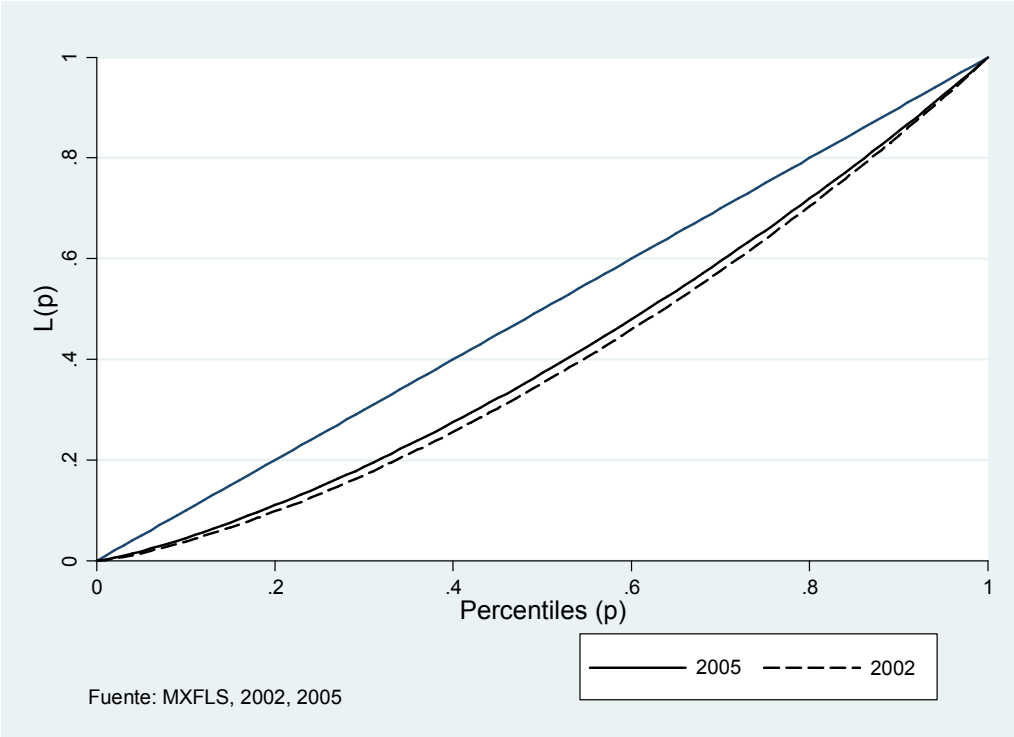
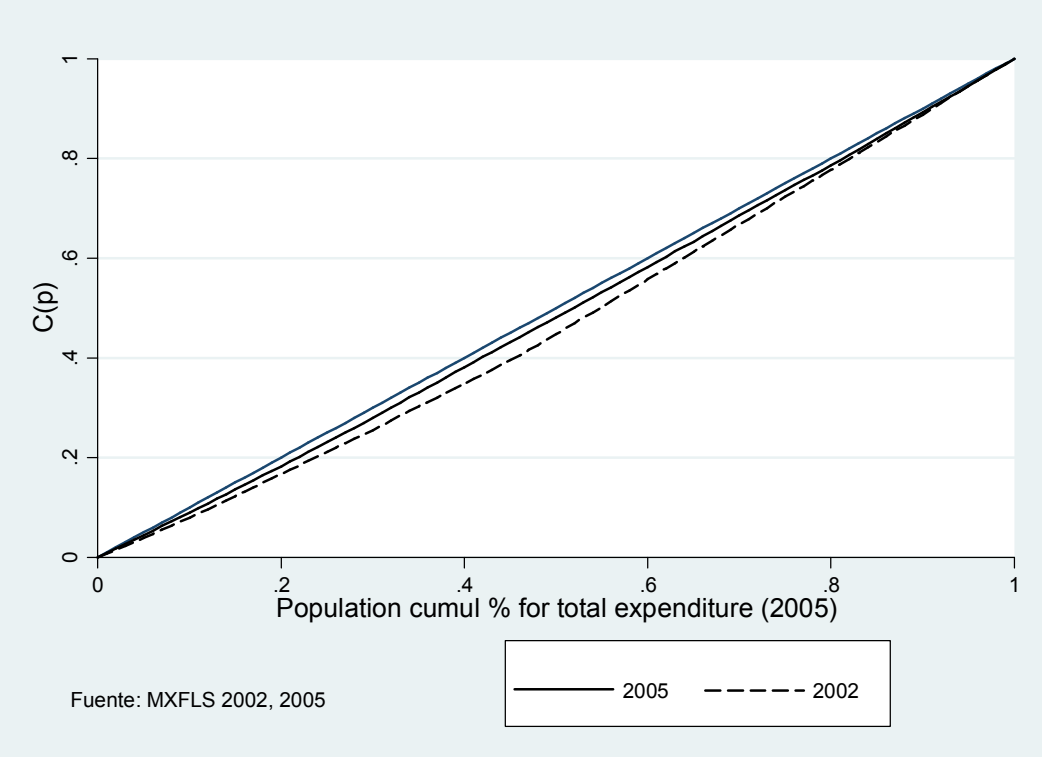


Table A2. Gini Index for cognitive skill and state.

Entidad	2002			2005			
	Score	Gini	S.E.	Score	Gini	S.E.	Gini Difference
Michoacán	9.37	0.2235	0.0065	11.20	0.1779	0.0048	-0.0456
Oaxaca	9.59	0.2331	0.0073	11.13	0.2007	0.0072	-0.0324
Puebla	9.93	0.2219	0.0076	11.17	0.1990	0.0090	-0.0229
México	10.07	0.2086	0.0061	11.50	0.1667	0.0061	-0.0419
Guanajuato	10.18	0.2140	0.0067	10.70	0.1849	0.0067	-0.0291
Veracruz	10.67	0.2024	0.0019	11.60	0.1745	0.0018	-0.0279
BCS	10.74	0.2083	0.0101	11.76	0.1787	0.0093	-0.0296
Jalisco	11.17	0.1937	0.0088	11.53	0.1787	0.0075	-0.0150
Sinaloa	11.19	0.1919	0.0065	12.60	0.1496	0.0054	-0.0423
Coahuila	11.24	0.1813	0.0072	11.73	0.1628	0.0072	-0.0184
Yucatán	11.32	0.2086	0.0066	11.64	0.1777	0.0058	-0.0308
Morelos	11.50	0.1648	0.0076	11.74	0.1737	0.0089	0.0089
Nuevo León	11.88	0.1643	0.0058	11.86	0.1632	0.0059	-0.0012
Durango	12.00	0.1604	0.0062	11.77	0.1565	0.0061	-0.0038
DF	12.23	0.1717	0.0119	12.07	0.1715	0.0126	-0.0001
Total	10.71	0.1671	0.0070	11.57	0.1512	0.0071	-0.0159

Fuente: MXFLS 2002, 2005

Figure A2. The Concentration's Curves of cognitive skill



Cuadro A3. Formación de habilidades cognitivas de corto plazo

Variable dependiente: Puntaje cognitivo 2005	All sample		5-7 años de edad		8-12 años de edad	
	(1)	(2)	(1)	(2)	(1)	(2)
Características del niño						
Puntaje cognitivo	0.139***	0.133***	0.0942***	0.0899***	0.224***	0.212***
	[0.0212]	[0.0226]	[0.0250]	[0.0264]	[0.0295]	[0.0314]
Edad (2005)	0.424***	0.408***	0.432***	0.410***	0.272**	0.266**
	[0.0472]	[0.0489]	[0.0792]	[0.0852]	[0.121]	[0.126]
Género (hombre=1)	0.0896	0.100	0.245	0.225	-0.168	-0.0981
	[0.129]	[0.133]	[0.162]	[0.163]	[0.185]	[0.190]
Variables de inversión						
Asiste a la escuela	0.337	0.485**	0.265	0.443	1.064*	1.050
	[0.236]	[0.243]	[0.258]	[0.268]	[0.642]	[0.649]
Ayudó a hacer tareas o a estudiar	0.413***	0.421***	0.400**	0.388*	0.452**	0.504**
	[0.142]	[0.144]	[0.198]	[0.203]	[0.192]	[0.206]
Alguna vez recibió beca PROGRESA	0.280	0.513**	0.746	1.084*	0.128	0.318
	[0.214]	[0.232]	[0.628]	[0.562]	[0.247]	[0.269]
Características de la madre o tutor (2002)						
Puntaje cognitivo	0.0891***	0.101***	0.129***	0.136***	0.0314	0.0526*
	[0.0205]	[0.0198]	[0.0277]	[0.0291]	[0.0283]	[0.0272]
Escolaridad (primaria)	0.193	0.0289	-0.154	-0.370	0.653**	0.595*
	[0.321]	[0.328]	[0.402]	[0.408]	[0.316]	[0.332]
Escolaridad (secundaria)	0.796**	0.561	0.510	0.280	1.138***	0.923**
	[0.342]	[0.352]	[0.417]	[0.431]	[0.370]	[0.388]
Escolaridad (media o superior)	1.414***	1.129***	1.174***	0.833*	1.614***	1.453***
	[0.358]	[0.365]	[0.447]	[0.453]	[0.373]	[0.394]
Pertenece a grupo indígena	-0.444*	-0.300	-0.312	-0.143	-0.637***	-0.533**
	[0.234]	[0.204]	[0.283]	[0.248]	[0.241]	[0.244]
(HH) Tamaño	-0.0954**	-0.101**	-0.117**	-0.120**	-0.0362	-0.0404
	[0.0441]	[0.0453]	[0.0558]	[0.0583]	[0.0682]	[0.0711]
(HH) con niño(s) menor a 5 años	-0.146	-0.181*	-0.0690	-0.0947	-0.300*	-0.360**
	[0.101]	[0.0995]	[0.107]	[0.102]	[0.162]	[0.170]
(HH) con adulto(s) > 18 años	0.213***	0.245***	0.255**	0.284***	0.120	0.146
	[0.0795]	[0.0840]	[0.0978]	[0.101]	[0.116]	[0.123]
Quintil gasto II	0.748***	0.644***	1.001***	0.891***	0.267	0.172
	[0.234]	[0.235]	[0.259]	[0.263]	[0.327]	[0.339]
Quintil gasto III	0.508**	0.486**	0.562**	0.483*	0.318	0.386
	[0.233]	[0.244]	[0.263]	[0.277]	[0.330]	[0.355]
Quintil gasto IV	0.643***	0.667***	0.760***	0.714***	0.414	0.556*
	[0.216]	[0.214]	[0.263]	[0.268]	[0.312]	[0.326]
Quintil gasto V	0.835***	0.796***	0.772**	0.704**	0.840**	0.839**
	[0.273]	[0.285]	[0.325]	[0.341]	[0.354]	[0.374]
Características de la localidad						
Cuenta con biblioteca		0.380***		0.416**		0.340**
		[0.144]		[0.195]		[0.167]
Proporción de escuelas con computadoras para alumnos		0.691*		0.786*		0.474
		[0.354]		[0.419]		[0.407]
Constant	4.729***	4.347***	4.937***	4.582***	5.222***	4.887***

	[0.559]	[0.608]	[0.852]	[0.920]	[1.451]	[1.531]
Observations	2797	2557	1683	1537	1114	1020
R-squared	0.194	0.221	0.156	0.183	0.213	0.239

*** p<0.01, ** p<0.05, * p<0.1 OLS regression with robust standard errors in brackets
Fuente: Ennvih 2002 y 2005

Table A4. Formación de habilidades cognitivas de corto plazo en niños de 5 a 12 años de edad. Análisis por quintil de gasto

Puntaje cognitivo 2005	Q1	Q2	Q3	Q4	Q5
Características del niño					
Puntaje cognitivo	0.142***	0.0836*	0.161***	0.120***	0.175***
	[0.0461]	[0.0487]	[0.0443]	[0.0415]	[0.0477]
Edad (2005)	0.510***	0.286***	0.366***	0.463***	0.395***
	[0.0976]	[0.0944]	[0.119]	[0.106]	[0.131]
genero (hombre=1)	0.0905	0.186	-0.208	0.229	0.0902
	[0.282]	[0.310]	[0.292]	[0.261]	[0.274]
Variables de inversión					
Asiste a la escuela	0.394	0.693	1.135**	-0.403	1.108
	[0.466]	[0.505]	[0.497]	[0.576]	[0.977]
Ayudó a hacer tareas o a estudiar	0.354	0.243	0.694**	0.219	0.294
	[0.300]	[0.324]	[0.317]	[0.264]	[0.306]
Alguna vez recibió beca PROGRESA	0.379	1.223**	-0.477	0.772	1.156**
	[0.543]	[0.494]	[0.453]	[0.529]	[0.482]
Características de la madre o tutor					
Puntaje cognitivo	0.0856	0.0868*	0.0865*	0.146***	0.0839
	[0.0609]	[0.0521]	[0.0492]	[0.0437]	[0.0512]
Escolaridad (primaria)	0.623	0.291	1.163	-1.144*	-2.262**
	[0.438]	[0.554]	[0.911]	[0.604]	[0.927]
Escolaridad (secundaria)	0.845	1.052*	1.336	-0.186	-1.703*
	[0.543]	[0.626]	[0.901]	[0.623]	[0.935]
Escolaridad (media o superior)	1.601**	1.842**	1.589*	1.020*	-1.406
	[0.684]	[0.711]	[0.908]	[0.558]	[0.917]
Pertenece a grupo indigena	-0.360	-0.801*	-0.203	-0.0497	0.0857
	[0.457]	[0.412]	[0.460]	[0.459]	[0.466]
(HH) Tamaño	0.0326	-0.117	-0.256**	-0.0969	-0.0560
	[0.115]	[0.101]	[0.112]	[0.0885]	[0.117]
(HH) con niño(s) menor a 5 años	-0.437**	-0.0768	-0.190	-0.124	-0.121
	[0.193]	[0.234]	[0.229]	[0.160]	[0.207]
(HH) con adulto(s) mayores a 18 años	0.149	0.371*	0.489***	0.247*	-0.00308
	[0.245]	[0.213]	[0.177]	[0.134]	[0.147]
Características de la localidad					
Cuenta con biblioteca	1.153***	-0.302	0.336	0.233	0.675*
	[0.334]	[0.317]	[0.308]	[0.282]	[0.382]
Proporción de escuelas con computadoras para alumnos	1.054	0.508	-0.126	1.156**	0.508
	[0.697]	[0.645]	[0.686]	[0.564]	[0.815]
Constant	2.302*	6.451***	4.507***	5.603***	6.913***
	[1.272]	[1.335]	[1.650]	[1.486]	[1.689]
Observations	513	494	503	515	532
R-squared	0.232	0.147	0.204	0.234	0.183

*** p<0.01, ** p<0.05, * p<0.1. OLS regression with robust standard errors in brackets

Fuente: Ennvih 2002 y 2005

Table A5. Formación de habilidades cognitivas de corto plazo en niños de 5 a 12 años de edad. Análisis por zona de residencia

Puntaje cognitivo 2005	**Rural <**	**Urbano de 2500-100 mil**	**Urbano < 100 mil**

	2,500		
Características del niño			
Puntaje cognitivo	0.116***	0.158***	0.127***
	[0.0349]	[0.0314]	[0.0413]
Edad (2005)	0.368***	0.467***	0.424***
	[0.0660]	[0.113]	[0.0993]
genero (hombre=1)	-0.0436	-0.277	0.553**
	[0.186]	[0.309]	[0.230]
Variables de inversión			
Asiste a la escuela	0.878***	-0.228	0.384
	[0.321]	[0.475]	[0.334]
Ayudó a hacer tareas o a estudiar	0.454**	0.574*	0.222
	[0.215]	[0.310]	[0.277]
Alguna vez recibió beca PROGRESA	0.543*	0.334	0.171
	[0.285]	[0.556]	[0.853]
Características de la madre o tutor			
Puntaje cognitivo	0.105***	0.0767	0.0973***
	[0.0344]	[0.0495]	[0.0246]
Escolaridad (primaria)	-0.281	1.218**	-0.669
	[0.417]	[0.516]	[0.629]
Escolaridad (secundaria)	0.0448	1.909***	-0.0346
	[0.475]	[0.585]	[0.672]
Escolaridad (media o superior)	0.778	2.350***	0.447
	[0.498]	[0.642]	[0.715]
Pertenece a grupo indigena	-0.644**	0.309	0.0464
	[0.300]	[0.281]	[0.239]
(HH) Tamaño	-0.0677	0.0619	-0.180**
	[0.0646]	[0.0887]	[0.0841]
(HH) con niño(s) menor a 5 años	-0.343**	0.196	-0.212*
	[0.157]	[0.170]	[0.111]
(HH) con adulto(s) mayores a 18 años	0.213	0.149	0.277***
	[0.143]	[0.205]	[0.0889]
Quintil gasto II	1.026***	0.378	-0.816*
	[0.310]	[0.398]	[0.444]
Quintil gasto III	0.727**	0.464*	-0.981**
	[0.349]	[0.235]	[0.389]
Quintil gasto IV	0.768**	0.611	-0.559*
	[0.314]	[0.436]	[0.329]
Quintil gasto V	0.925*	0.984**	-0.450
	[0.484]	[0.358]	[0.437]
Características de la localidad			
Cuenta con biblioteca	0.642**	-0.0674	-0.198
	[0.281]	[0.292]	[0.257]
Proporción de escuelas con computadoras para alumnos	0.490	0.0420	1.566**
	[0.449]	[0.709]	[0.596]
Constant	4.821***	3.124**	6.370***
	[0.812]	[1.349]	[1.265]
Observations	1252	474	831
R-squared	0.203	0.236	0.181

*** p<0.01, ** p<0.05, * p<0.1. OLS regression with robust standard errors in brackets. Fuente: Ennvih 2002 y 2005.