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Abstract:
While a large literature has focused on the impact of parental investments on child cognitive development, very little is known about the role of child's own investments. By using the Child Development Supplement of the Panel Study of Income Dynamics, we model the production of cognitive ability of adolescents and extend the set of inputs to include the child's own time investments. Looking at investments during adolescence, we find that child's investments matter more than mother's investments. On the contrary, looking at investments during childhood, it is the mother's investments that are more important.

Keywords: Time use, Cognitive ability, Child development, Adolescence

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Contents

1. Introduction

The objective of this research is to explore and compare the impacts of time investments by parents and children on child's cognitive outcomes during adolescence. The effect of parents' investment at different stages of child's life has been very much studied in the economics literature on skill formation, while the role of child's own investment as she matures has received very little attention insofar. Carneiro, Cunha, & Heckman (2003) and Cunha & Heckman (2008) are among the few papers including a model of cognitive and non-cognitive investments for older children where the latter are considered as decision makers.

Empirical studies generally find that the inputs in the cognitive production function have a different effect at different stages of the children's life. Family contribution in child development decreases with age, and this seems to suggest that there is less space for policy interventions in late childhood and adolescence. However, there can be other factors through which cognitive attainments can be improved in late childhood and adolescence when individuals become able to take independent decisions. Among these factors, a prominent one is expected to be the time investment actively made by the adolescents themselves. "What lies at the core of adolescent cognitive development is the attainment of a more fully conscious, self-directed and self-regulating mind." (Steinberg, 2005). During adolescence children become responsible for their actions, therefore their cognitive investments begin to depend on their own decisions, for example decisions on how much effort to invest in doing homework rather than watching television.

This paper provides the first empirical assessment of the role played by self investments of adolescents in shaping their cognitive development. We model the cognitive production function during adolescence by way of an augmented value added specification, where cognitive ability depends on a set of contemporaneous and lagged inputs and on lagged cognitive ability (see Todd & Wolpin, 2003, 2007). The crucial inputs we control for are the time the mother's spend with her child and the time the child spends on her own doing formative activities that improve cognitive development, which we call time inputs or time investments. Using the Child Development Supplement (CDS) of the Panel Study of Income Dynamics (PSID), we measure cognitive ability using a revised version of a set of intelligence tests developed by Woodcock and Johnson in 1977 (see Section 3 for more details). More specifically, we use two tests measuring reading abilities and a third test measuring mathematical skills. The contemporaneous test and inputs are measured when children are between 11 and 15 years old, while the lagged test and inputs are measured 5 years earlier when the children are between 6 and 10 years old.

We take the three cognitive tests as repeated measures of the latent child's general cognitive ability. In this way, we are able to account for the endogeneity of the lagged test, which is caused by its dependence on the unobserved child specific ability endowment (See Section 4). We are also able to remove the bias which arises from unobserved family characteristics by exploiting the presence of siblings in the sample. Our estimation results show that the time children spend on their own doing formative activities during adolescence affects their test scores much more than the time input by their mother. On the contrary, the time input by their mother during childhood matters more than the time input by the children. Our results are coherent with a production function of cognitive ability which changes in a significant way over the life cycle of the children and indicate a channel through which cognitive development can be influenced at later ages.

2. Background

Several surveys have shown that parental time investments on children have important impacts on child cognitive and non cognitive outcomes (see Carneiro & Heckman 2003; Ermisch &Francesconi, 2005; Haveman & Wolfe 1995). Since most socioeconomic surveys lack appropriate measures of parental time, most studies have been forced to use proxy measures such as mothers' employment (Bernal, 2008; Todd &Wolpin, 2007; Liu et al., 2010; Bernal & Keane, 2011). A more accurate measure of the time investments in children is provided by the time diary surveys, which usually contain detailed information on the time children spend in different activities together with their mother, their father and other adults. Nevertheless, there are only few papers that use time diaries to measure investments in children. Among these few exceptions are Hsin (2007, 2009) Carneiro & Rodriguez (2009) and Del Boca et al. (2013), who have used the Child Development Supplement (CDS) of the Panel Study of Income Dynamics (PSID) for the USA. These papers estimate the effect on children's skills of different measures of parental time investments. Carneiro & Rodriguez (2009) consider the total time spent with the mother; Hsin (2007) defines measures of maternal total time, engaged time and quality time; Del Boca et al. (2013) distinguish between the time the children spend with their mother and with their father, and between the time when the parents are actively engaged and when they are simply around.

As in these previous papers, we use time diaries surveys to measure parental time inputs, but the novelty of our paper is that we consider also the time children spend on their own.[2] How children spend time on their own becomes important as children grow into teenagers (Kooreman, 2007). This is because adolescents begin to take independent decisions on how to spend their time and these decisions can affect their cognitive development. However, children are rarely considered "active actors" in household behavioral models. There are only few examples of economic models which consider both children and parents as decision makers. Among these there are the models suggested by Carneiro et al. (2003), Lundberg et al. (2009), and Dauphin et al. (2011). Carneiro et al. (2003) consider an overlapping generation model for the child's skill production. More precisely, they consider a three-period model where parents decide human capital investments on children in period one and starting from period two onward, when the child becomes adult, she alone decides her own education and work. However, this model does not allow parents and children to be decision makers in the same period, and non-adult children are supposed to have no influence on their cognitive investments. On the contrary, Dauphin et al. (2011) and Lundberg et al. (2009) allow for parents and children to be decision makers at the same time. By estimating a collective model, Dauphin et al. (2001) provide evidence that children, who are aged 16 and over and living with parents, are active economic agents and influence the household decision process, at least when looking at decisions on household consumption and labour supply. Lundberg et al. (2009), estimate a non-cooperative model to study the decision-making by children distinguishing between decisions taken on their own and shared with their parents. They find that the probability of taking independent decisions increases sharply between age 10 and 14.

Given that during adolescence children begin to take decisions on their own on how to use their time, cognitive production models for adolescents should include the time children spend on their own doing formative activities. The question is then how to define formative activities and consequently time investments by children.

[2] The only other paper which considers the time spent by children in educational activities done on their own is Dolton et al (2003), but they analyze adult children who are already at the university.

In the economic literature there are a few papers that have defined time investment by parents (see, beside the papers cited at the beginning of this section, Price, 2008 and Guryan et al., 2008). The common approach is to consider the time parents spend with their children in formative activities such as reading, doing homework, playing sports, and exclude activities which are usually considered detrimental or not beneficial to the child's development, as for example watching television. A natural extension of this definition to time investments by the children themselves would consider the time the child spends on her own doing formal and informal educational activities as well as socializing and sports activities which can contribute to the child development. This is actually the definition which we will adopt in our empirical application (see for more details Section 3).

Different definitions of children's time investments have been used in other papers, but without distinguishing the time the child spends on her own and the time she spends actively supervised by an adult. Fiorini & Keane (2011) consider time use diaries from the Longitudinal Study of Australian Children to estimate the effect of time children spend doing a set of different activities (bed, school-day care, educational activities with parents, educational activities with adults other than parents, general care with parents, general care with adults other than parents, social activities, media, not sure what child was doing), but they do not consider separately the time children spend on their own. Other papers have focused on the time children spend reading or doing homework as opposed to time spent watching television, and they generally find positive and significant effects of the former activities and a negative or insignificant effect of the latter on children's cognitive skills.

From the psychological literature, we learn that reading habits are positively correlated with children's achievement, measured by vocabulary, reading comprehension and verbal fluency (Anderson et al., 1988; Taylor et al., 1990; Cunningham & Stanovich, 1991, 1993). For instance, Searls et al. (1985) look at the relationship between reading abilities and different activities conducted at home by adolescents: watching television, reading and doing homework. They find that children who watch television extensively are among the poorest readers, even if they also report spending a great deal of time doing spare time reading or homework, homework activities increase reading abilities of adolescents, while spare time reading hours are associated with the highest reading performance for all the age categories. A similar result is found in Anderson et al. (1988). They study the relationship between out-of-school activities (as listening to music, playing sport and reading a book) on subsequent reading achievements; they find that among all the ways children spend their time, reading books was the best predictors of several measures of reading achievement.

These previous empirical results on how children spend their time and on how this affects their cognitive abilities suggest that children's time investments are important inputs in the cognitive development process. If we split the children's investment in the time invested on their own and the time invested under the active supervision of an adult, the former will be presumably more and more important as they get older, while the latter will get less important. Empirical evidence shows that the effect of parental investments on cognitive skills reduces rapidly across age (see Cunha & Heckman, 2008). In particular, looking at mothers' and fathers' time investments, Del Boca et al. (2013) find that the time parents spend actively engaged with their child has an effect that decreases with child's age. This would suggest that policies directed at increasing parental time investments during adolescence would be less effective than policies implemented early in the child's life. On the contrary, policies directed at increasing child investments in themselves could improve adolescents' cognitive development.[3]

3. Data and Preliminary Evidence

Our analysis relies on the Child Development Supplement (CDS), funded by the National Institute of Child Health and Human Development (NICHD). The CDS covers a maximum of two children for a subsample of households interviewed in the Panel Study of Income Dynamics.[4] About 3500 children aged 0-12 (from about 2400 households) were first interviewed in 1997, and then followed in two subsequent waves, 2002/03 and 2007. The number of successful re-interviews was quite high: 91% in the second wave, 90% in the third one. The CDS collects information on cognitive and non-cognitive development of the sampled children, as well as their time diaries and other individual and family characteristics. All the household and parental variables included in the PSID survey are also available for the CDS children. In our analysis we include teenagers aged between 11 and 15 and living with both biological parents. To avoid small sample size issues, we pool two cohorts of children,

[3] Mancini et al. (2011) consider time spent in reading activities by the children on their own, and they detect imitation as a channel of intergenerational transmission of the reading habit. This result seems to suggest that although parents' time investments are not directly affecting adolescents' cognitive skills, they may affect them indirectly through the transmission of time use habits.

[4] The Panel Study of Income Dynamics is a USA longitudinal survey of a nationally representative sample of individuals and families, started in 968 with a sample of 4800 families. It collects yearly individual information on economic, demographic, sociological, and psychological variables and well-being.

born respectively in 1982-1986 (adolescents in 2002) and in 1987-1992 (adolescents in 2007) and get a sample of 726 children. This is the *main sample* used in the descriptive statistics in this section. For the estimation of our production models we will use the subsample of siblings, *sibling sample*, which allows us to consider the family fixed effect estimation. We have 202 pairs of siblings (404 children out of the 726 included in the main sample). The main summary statistics for the main and sibling samples are reported in the Appendix in Tables A1 and A2 respectively.

3.1. Time Investments

Crucial to our research question is the availability of detailed information on child's time use allocation for one randomly selected week-day and one randomly selected weekend- day. Time diaries contain for each day recording of activities performed in the 24 hours on a continuous basis.[5] Each spell of a given activity comes with information on its duration, location and on whether the activity was done by the child on her own, in presence of somebody not actively participating or in presence of somebody actively engaged.

This allows us to define a measure of weekly parental time input as well as a measure of weekly child's own time investment.[6] We measure the former as the time the parent spends actively engaged with the child reading, doing homework, doing arts and crafts, doing sport, playing, attending performances and museums, engaging in religious activity, having meals and talking with the child, or providing personal care for the child. This aggregate measure of parental investment corresponds to the parent's quality time defined by Price (2008).[7] It is meant to include all the activities in which either the child is the primary focus or there is a sufficient interaction between the parent and the child. The positive relationship between the frequency of activities such reading, playing or eating with children and their outcomes is well documented in the literature (see Price, 2008, Section II for a concise review). The positive productivity of both mother's and father's active time has also been very recently documented by Del Boca et al. (2013) who have estimated a structural model of household choice on a sample of children in the age group 3-16 from the PSID CDS dataset.

[5] Activities are coded and registered from midnight of one day (00:00) to midnight of the following day (24:00), using a 24 hour clock. The ending time of an activity coincides with the starting time of the following activity, so that there are no gaps in time.

[6] The weekly measure is obtained multiplying by five the week-day time, and summing the result with the weekend-day time multiplied by two.

[7] Price (2008) derives parental time inputs from the parents time diaries, which are available in the American Time Use Survey.

In order to take the novel perspective of the child's own investments in her development process, we select from the above listed activities those that improve the child human capital when performed autonomously by the child (i.e. either on his own or without any one actively engaged). The resulting aggregate measure of child's own investment includes - beside the time spent doing homework - all active leisure components such as reading, doing arts and crafts, doing sport, playing, attending performances and museums, engaging in religious activity. Both intuition and scientific evidence highlight that human capital includes components other than formal knowledge, as personal interaction skills that can be enhanced by time spent with friends or engaging in physical activities. Cardoso et al. (2010) consider socializing together with reading and studying as activities related to the acquisition of human capital, and opposed to passive leisure such as television watching, often portrayed as detrimental and crowding out other useful activities. Felfe et al. (2011) report that a positive link between participation in active leisure sport activities and educational attainment is well established for adolescence, and show that sport club participation during kindergarten and primary school has a positive effect on school performance.

The upper part of Table 1 contains the composition of the child's own time inputs in childhood age (6-10) and adolescence (11-15) respectively. The total active time spent by children on their own increases of about one hour a week (25%), on average, across the two stages of their life. The reading and homework activities bring the largest contribution to this increase (respectively about 16 and 48 minutes per week on average), followed by the playing category (with an average increase of about 13 minutes per week). On the contrary, sport and arts activities appear less frequently performed on average during adolescence compared to childhood. The bottom panel of the same table shows a sharp decrease of the mother's time investments from the childhood to the adolescence period. Mothers spend on average about 9 hours and a half per week actively engaged with their children aged 6 to 10 years, but only 5 hours and a half minutes when their children become adolescents. All categories of mother's time input but religious activity diminish across the two child's life stages. In the Appendix Table A3 we report the father's composition of time inputs. The total time fathers spend with children decline with child's age: on average of 6 hours a week with their children aged 6 to 10 years, and only 4 when the children 11 to 15. However, time spent in helping with homework, talking and attending performances increases slightly.

Table 1: Mother's and child's time input composition – Main sample

	Weekly time (hours)							
	Child's age range 6-10*				Child's age range 11-15**			
	Mean	SD	Min	Max	Mean	SD	Min	Max
Own time inputs								
Total time	4.08	5.15	0	30.92	5.12	6.86	0	41.25
Reading	0.69	1.79	0	24	0.96	2.5	0	21.83
Homework	0.46	1.72	0	17.5	1.25	3.52	0	29
Playing	2.27	3.81	0	24.75	2.48	5.1	0	41.25
Arts and craft	0.27	1.14	0	11.25	0.2	1.24	0	19.75
Sport	0.28	1.3	0	22.1	0.16	0.95	0	15
Attending performances	0	0	0	0	0.01	0.2	0	5.33
Attending museums	0	0	0	0	0	0	0	0
Religious activity	0.11	0.7	0	6.33	0.08	0.56	0	7.17
Mother's time inputs								
Total time	9.47	7.08	0	40.42	5.46	5.2	0	35.42
Reading	0.5	1.21	0	11.25	0.11	0.84	0	12.33
Homework	0.24	1.12	0	10.83	0.11	0.84	0	11.17
Playing	9.47	7.08	0	40.42	5.46	5.2	0	35.42
Talking	0.5	1.21	0	11.25	0.11	0.84	0	12.33
Arts and craft	0.24	1.12	0	10.83	0.11	0.84	0	11.17
Sport	0.41	1.47	0	15	0.09	0.68	0	10.67
Attending performances	0.14	1.01	0	13.33	0.1	0.9	0	13.333
Attending museums	0.05	0.56	0	9.5	0	0	0	0
Religious activity	0.78	2.07	0	14.32	0.78	2.21	0	20
Meals	4.57	3.18	0	22.17	3.11	2.91	0	21.75
Personal care	1.2	2.5	0	24.17	0.24	1.21	0	16.17
Number of observations: 726			0				0	

* years 1997-2002, pooled
** years 2002-2007, pooled

3.2. Cognitive Outcomes

The cognitive tests come from the Woodcock-Johnson Revised Tests of Achievement (WJ-R), "a well-established and respected measure that provides researchers with information on several dimensions of intellectual ability" CDS User Guide). The CDS provides three of such cognitive test scores measuring reading and mathematics achievements: the Letter-Word Identification, Passage-Comprehension, and Applied-Problems test scores. These tests were administered to respondents aged 6 years and older by the interviewer, following a standardized administrative protocol and adjusting the test by difficulty according to the respondent age (see CDS User Guide for details). Each of these three tests provides a score which is a measure of the cognitive ability. The Letter-Word Identification Score (LWS) measures symbolic learning (matching pictures with words) and reading identification skills (identifying letters and words). It starts from the easiest items (identification of letters and pronunciation of simple words), progressing to the more difficult items. The Passage Comprehension Score (PCS) assesses comprehension and vocabulary skills through multiple-choice and fill-in-the-blank formats. The Applied Problems Score (APS) measures mathematical skills in analyzing and solving practical problems. The test scores are available in both raw and standardized formats. The former essentially counts the number of items correctly answered, while the latter are obtained standardizing the raw scores according to the respondent's age.[8] We use the standardized measures throughout our analysis.

3.3. Time Investments and Cognitive Ability: Preliminary Evidence

In Tables 2 and 3 we provide descriptive evidence on the link between time investments and children cognitive outcomes. In Table 2 we look at the differences between average test scores for adolescents dividing them in two groups: those receiving a high level of inputs from their mother (higher than the average) and those receiving a low level of inputs (lower than the average). It can be noticed that children receiving low time investments from their mother in adolescence have essentially the same outcomes in adolescence as children receiving high time investments, while the time spent with the mother actively engaged in childhood is associated with significant differences for two out of the three cognitive measures considered during the adolescence period.

Table 2: Differences in average test scores by time inputs received by mother – Main sample

		Contemporaneous input (age 11-15)		
	Obs	LWS Average	PCS Average	APS Average
Sample	726	105.842	104.055	107.135
Time inputs by mother				
High (higher than average)	288	106.028	104.653	106.833
Low (lower than average)	438	105.719	103.662	107.333
Difference		0.308	0.990	-0.5
Standard error		1.275	1.135	1.150
		Lagged input (age 6-10)		
	Obs	LWS Average	PCS Average	APS Average
Sample	726	105.842	104.055	107.135
Time inputs by mother				
High (higher than average)	320	106.7	105.872	108.028
Low (lower than average)	406	105.165	102.623	106.431
Difference		1.534	3.249***	1.597^
Standard error		1.254	1.112	1.131

Two sided t test for H_0: Difference=0, LWS=Letter-Word Identification Score, PCS=Passage Comprehension Score, APS=Applied Problem Score

^, *, **, *** statistically significant at15%, 10%, 5%, 1% level respectively

[8] The age standardization process allows for comparison of children of different ages, eliminating the discrepancy in the results due to age differences.

Turning to child's own investments in Table 3, the pattern is reversed, and contemporaneous inputs display a much stronger relationship with adolescents' outcomes with respect to past inputs. The highly significant differences in the test scores between children with high time investments n human capital building activities and those with low time investments strongly support our investigation about the relevance of autonomous decisions taken by children in this stage of life.

Table 3: Differences in average test scores by child own time inputs – Main sample

		Contemporaneous input (age 11-15)		
	Obs	LWS Average	PCS Average	APS Average
Sample	726	105.842	104.055	107.135
Child's time inputs				
High (higher than average)	249	108.566	107.365	110.438
Low (lower than average)	477	104.419	102.327	105.411
Difference		4.147***	5.038***	5.026***
Standard error		1.305	1.155	1.170
		Lagged input (age 6-10)		
	Obs	LWS Average	PCS Average	APS Average
Sample	726	105.842	104.055	107.135
Child's time inputs				
High (higher than average)	268	108.160	105.944	108.585
Low (lower than average)	458	104.484	102.950	106.296
Difference		3.675***	2.994***	2.300**
Standard error		1.285	1.145	1.162

Two sided t test for H_0: Difference=0, LWS=Letter-Word Identification Score, PCS=Passage Comprehension Score, APS=Applied Problem Score
*, **, *** statistically significant at10%, 5%, 1% level respectively

4. Modelling Cognitive Achievement Production Function During Adolescence

We model the cognitive achievement production function during adolescence considering inputs which reflect decisions by schools and families as well as by the adolescents themselves. We also take into account the fact that the cognitive development is a cumulative process by considering both contemporaneous and past investments.

Accordingly we adopt the following cognitive production function for adolescents aged between 11 and 15 years old

$$Y_{ijt} = F_t\left(X_{ijt}, X_{ijt-5}, X_{ijt-10}, \mu_{ij}\right) \qquad (1)$$

where the outcome Y_{ijt} is a test score measuring the cognitive achievement for adolescent i in family j at t years old, t=11,...,15, and the arguments are given by

- the vector of contemporaneous cognitive investments during adolescence by the child herself, X^{C}_{ijt}, her family, X^{F}_{ijt}, and her school, $X^{S}_{ijt}, X^{'}_{ijt} = [X^{C'}_{ijt}, X^{F'}_{ijt}, X^{S'}_{ijt}]$;
- the corresponding vector of inputs during late childhood (5 years earlier), $X^{'}_{ijt-5} = [X^{C'}_{ijt-5}, X^{F'}_{ijt-5}, X^{S'}_{ijt-5}]$;
- the corresponding vector of inputs during early childhood (10 years earlier), $X^{'}_{ijt-10} = X^{C'}_{ijt-10}, X^{F'}_{ijt-10}, X^{S'}_{ijt-10}$;
- her cognitive endowment μ_{ij}.

his production function is similar to the one considered by previous work on child cognitive development with the main difference that it adds the investments made by the children themselves beside the inputs by families and schools (see Todd &Wolpin 2003, 2007).

In our sample we do not observe a general measure of cognitive ability Y_{ijt}, but we observe three different specific skills measured by the Letter-Word Identification, Passage-Comprehension, and Applied-Problems test scores. We indicate these three measured skills with Y_{kijt} where the subscript k denotes each of the three cognitive abilities and we assume that

$$Y_{kijt} = Y_{ijt} + \varepsilon_{kijt}, \tag{2}$$

where ε_{kijt} measures the deviation of the skill k, Y_{kijt}, from the general latent ability, Y_{ijt}, which is assumed to be identically and independently distributed across skills, individuals and households, with variance σ^2_{ε} and unrelated with the production function inputs and innate ability.

By assuming that the production function is additive separable, linear in its arguments and invariant during the adolescent period from 11 to 15, it can be rewritten as

$$Y_{kijt} = \beta_0 + \beta_1 X_{ijt} + \beta_2 X_{ijt-5} + \beta_3 X_{ijt-10} + \mu_{ij} + \varepsilon_{kijt}, \qquad (3)$$

or more explicitly as

$$\begin{aligned} Y_{kijt} = \beta_0 &+ \beta_1^C X_{ijt}^C + \beta_1^F X_{ijt}^F + \beta_1^S X_{ijt}^S + \beta_2^C X_{ijt-5}^C + \beta_2^F X_{ijt-5}^F + \beta_2^S X_{ijt-5}^S \\ &+ \beta_3^C X_{ijt-10}^C + \beta_3^F X_{ijt-10}^F + \beta_3^S X_{ijt-10}^C + \mu_{ij} + \varepsilon_{kijt} \end{aligned} \qquad (4)$$

where β_0 is the intercept, $\beta_1 = [\beta_1^C, \beta_{1,}^F, \beta_1^S]$, $\beta_2 = [\beta_2^C, \beta_{2,}^F, \beta_2^S]$, and $\beta_3 = [\beta_3^C, \beta_{3,}^F, \beta_3^S]$ are vectors of coefficients corresponding to contemporaneous and 5-year and 10-year lagged inputs from children themselves, families and schools. Model (4) is what Todd & Wolpin (2003) call the *cumulative model*, that is a model where the outcome at age t, during adolescence, depends on inputs at different points of the child's life, more specifically in early childhood, late childhood and adolescence.

In our empirical application we are unable to measure inputs in early childhood and therefore we have to drop these inputs from the model. This is a minor issue for cognitive investments during early childhood by the child herself, X_{ijt-10}^C, because very young children spend very little time without any adult actively engaged in what they are doing. On the contrary, the omission of inputs from school and parents in early childhood can be relevant; but, since our final estimation uses a sibling difference approach, we are effectively controlling for all early childhood inputs which are invariant between siblings. Furthermore, our estimation of the effect of child's and mother's time investments is consistent even if there are differences between siblings in the unobserved inputs as long as the sibling differences in observed investments are uncorrelated with the sibling differences in unobserved inputs once controlled for their differences in the other control variables.

We measure family investments by looking at the time the mother spends actively engaged with her child, whereas we measure children investments in their own cognitive development by the time they spend in formative activities on their own (see Section 3 for details on these definitions). These time inputs are measured in two points in the child's life, when she is adolescent between 11 and 15 years old and 5 years earlier when she still in her childhood and aged between 6 and 10. Finally we also control for gender, children birth order, birth cohort

1982-86 (1987-1991), and for the mother's and the child's age. We do not explicitly consider school inputs, but, as in Rosenzweig & Wolpin's (1994), we assume that
there are no significant differences in the school inputs between two siblings who grow up in the same family and live in the same neighborhood, so that we can adopt a family fixed effect estimation to take account of the omission of school inputs.

Given two siblings i and i' and differentiating the cumulative model produces

$$DY_{kijt} = \beta_1^C DX_{ijt}^C + \beta_1^F DX_{ijt}^F + \beta_2^C DX_{ijt-5}^C + \beta_2^F DX_{ijt-5}^F + D\mu_{ij} + D\varepsilon_{kijt} \qquad (5)$$

where DA_{ijt} denotes the difference of the variable A between sibling i and i'.[9] Note that, we assume that

- either siblings have equal school investments in early childhood, late childhood and adolescence and equal parental and self investments during early childhood;
- or differences between siblings in unobserved investments by the schools, families and children are uncorrelated with observed sibling differences in investments once controlled for differences in the control variables.

If the child endowment μ_{ij} is composed by a family and a child specific component, $\mu_{ij} = \mu_j^F + \mu_{ij}^C$, then $D\mu_{i_j}^F$ also cancels out. Consequently, using family fixed effect estimation, we implicitly allow the cognitive achievement to depend on school inputs and the inputs to depend on family endowments, but we are unable to take account of the possible dependence of inputs on child specific endowments or on past cognitive achievements. Parents' and children's own time investments may depend on the child's past cognitive tests. For example, a low test score obtained in the past can encourage parents to invest more time with their children in order to improve their performance. To control for this dependence between lagged cognitive ability and inputs, we add the lagged cognitive ability as explanatory variable in the cumulative model, which yields the *augmented value added model* (as defined by Todd & Wolpin, 2007)

[9] The difference in the variables between two siblings is taken in the same calendar period, meaning that two siblings can have different ages but both of them must be in the age group 11-15.

$$Y_{kijt} = \delta_0 + \delta_1 X_{ijt} + \delta_2 X_{ijt-5} + \rho Y_{ijt-5} + \mu_{ij} + \varepsilon_{kijt} \quad (6)$$

Notice that we do not observe the lagged cognitive ability Y_{ijt-5}, but we observe three measures of specific skills as for the contemporaneous ability. Let then denote these three specific skills measured 5 years earlier with Y_{kijt-5} where the subscript k indicates each of these skills and, as for the contemporaneous ability, let us assume that

$$Y_{kijt-5} = Y_{ijt-5} + \varepsilon_{kijt-5} \quad (7)$$

where ε_{kijt-5} measures the deviation of the skill k in $t-5$ from the general latent ability in $t-5$. As for ε_{kijt}, we assume that ε_{kijt-5} is identically and independently distributed across skills, individuals and households, with variance σ^2_{ε}, and unrelated with inputs and innate ability, but we allow ε_{kijt} and ε_{kijt-5} to be correlated. More precisely we assume that the persistence in ε_{kijt} is identical to the persistence in Y_{ijt}, meaning that the both ε_{kijt} and Y_{ijt} have an identical net autocorrelation (where net means after controlling for the explanatory variables in the production model), which is equal to ρ.[10] By replacing the unobserved latent ability Y_{ijt-5} with the observed Y_{kijt-5}, the value added model becomes

$$Y_{kijt} = \delta_0 + \delta_1 X_{ijt} + \delta_2 X_{ijt-5} + \rho Y_{kijt-5} + \mu_{ij} + u_{kijt} \quad (8)$$

where $u_{kijt} = \varepsilon_{kijt} - \rho\varepsilon_{kijt-5}$. The correlation between Y_{kijt-5} and the error term u_{kijt} would generally bias the estimation, but under the assumption that ε_{kijt} and Y_{ijt} have equal net autocorrelation ρ, we can prove that the asymptotic bias caused by this issue cancels out. More precisely the estimation of ρ using ordinary least squares converges asymptotically to

$$p\lim \rho_{OLS} = \rho \frac{Cov(\mu_{ij}, M_X Y_{kijt-5})}{Var(M_X Y_{kijt-5})} + \frac{Cov(\varepsilon_{kijt}, \varepsilon_{kijt-5})}{Var(M_X Y_{kijt-5})} - \rho \frac{Var(\varepsilon_{kijt-5})}{Var(M_X Y_{kijt-5})}$$

[10] In this work by autocorrelation we mean correlation between a variable and the corresponding variable measured 5 years earlier. Notice also that Y and Y-5 have equal variance because we standardize our measures of abilities.

where M_X is the projection matrix on the space orthogonal to the one generated by the variables $X' = (X'_{ijt}, X'_{ijt-5})$, $\frac{Cov(\mu_{ij}, M_X Y_{kijt-5})}{Var(M_X Y_{kijt-5})}$ is the asymptotic bias caused by the omission of the unobserved individual endowment μ_{ij}, while $\left(\frac{Cov(\varepsilon_{kijt}, \varepsilon_{kijt-5})}{Var(M_X Y_{kijt-5})} - \rho \frac{Var(\varepsilon_{kijt-5})}{Var(M_X Y_{kijt-5})} \right)$ is the asymptotic bias caused by the correlation between the error term μ_{kijt} and the lagged test Y_{kijt-5}. This last bias cancels because we have assumed that

$$\frac{Cov(\varepsilon_{kijt}, \varepsilon_{kijt-5})}{\sqrt{Var(\varepsilon_{kijt-5})Var(\varepsilon_{kijt})}} = \frac{Cov(\varepsilon_{kijt}, \varepsilon_{kijt-5})}{Var(\varepsilon_{kijt-5})} = \rho \qquad (9)$$

As done before for the cumulative model, we reduce the bias caused by the omission of μ_{ij} by expressing the model (8) as differences between siblings (family fixed effect estimation) and therefore controlling for unobserved school inputs and family endowments and characteristics that are invariant between siblings,

$$\begin{aligned} DY_{kijt} &= \delta_1^C DX_{ijt}^C + \delta_1^F DX_{ijt}^F + \delta_2^C DX_{ijt-5}^C + \delta_2^F DX_{ijt-5}^F \\ &+ \rho DY_{kijt-5} + D\mu_{ij}^C + D\mu_{kijt} \end{aligned} \qquad (10)$$

Using differences between siblings eliminates the unobserved family specific endowment μ_{ij}^F and reduce the correlation between μ_{ij} and Y_{kijt-5}. Nevertheless there is still an issue of endogeneity of the lagged cognitive test variable. If child's unobserved ability μ_{ij}^C enters the production function each period and not through a one-time initial endowment process, a positive correlation will exist between the (sibling differenced) lagged cognitive test, DY_{ijt-5}, and the (sibling differenced) child specific endowment component, μ_{ij}^C. This can cause an upward bias for ρ which can contaminate the inputs coefficients as well (Andrabi et al., 2011).

We solve this last issue of endogeneity by using observations on three different skills available for each child and applying an individual fixed effect estimation to control for child specific endowment that may differ across siblings. This method has been called the within-pupil between-subject estimation by Dee (2005, 2007), who has used it to estimate the effect of teachers characteristics on test scores. Under the assumptions stated above, it can be proven that the individual fixed effect estimation converges to

$$p\lim \rho_{IndFE} = \frac{Cov(\varepsilon_{kijt}, \varepsilon_{kijt-5})}{Var(\varepsilon_{kijt-5})} = \rho \qquad (11)$$

Note that the inputs do not vary across the three tests implying that individual fixed effect estimation can produce estimates for ρ but not for β_1^C, β_1^F, β_2^C and β_2^F. Nevertheless, we can replace ρ with its estimate in

$$\begin{aligned} DY_{kijt} - \rho DY_{kijt-5} &= \delta_1^C DX_{ijt}^C + \delta_1^F DX_{ijt}^F + \delta_2^C DX_{ijt-5}^C + \delta_2^F DX_{ijt-5}^F \\ &+ D\mu_{ij}^C + D\mu_{kijt} \end{aligned} \qquad (12)$$

and use family fixed effect estimation to produce estimates for the coefficients δ_1^C, δ_1^F, δ_2^C, δ_2^F. Thanks to this novel two-step estimation we obtain results that are purged of the bias induced by the lagged test regressor and are consistent under the assumption that the whole dependence between inputs and child's innate ability is channeled through observed achievements or family endowments or characteristics that are invariant between siblings. We are actually not the first to assume that different cognitive test scores are related to a same latent cognitive ability and to use the multiplicity of measures to solve the issue of endogeneity of the lagged test. For example Cunha & Heckman (2008) use multiple measures of tests and inputs to derive three latent measures corresponding to cognitive and non-cognitive abilities and investment. Furthermore, they use multiple measures of tests and inputs to instrument the lagged tests and inputs in their cognitive development model (see Pudney, 1982 for more details on this other type of estimation). Our procedure imposes some different restrictions, but it is simpler and has the advantage to distinguish between parents and children inputs and therefore allows us to evaluate the contribution of children decisions on their cognitive development process.

Notice that the consistency of the family fixed effect estimation of the augmented value added model requires that neither parental and school investments be identical between siblings nor that they be uncorrelated with lagged test scores. Since the seminal paper of Behrman et al. (1982), several studies have tried to explain why parental investments differ between siblings and have examined whether these investments compensate or reinforce children difference in abilities. Bernal (2008) for example finds that the compensating behavior seems to dominate when looking at time investments of mothers. We take account that the mother's' investment may compensate or reinforce for differences between her children abilities by controlling for lagged test score realizations. We assume that any other unobserved ability is either identical between siblings or if a difference exists this is uncorrelated with the sibling differences in observed inputs once controlled for their gaps in the lagged test and other control variables.

5. Estimation results of the cognitive production model

In Table 4 we report our main estimation results for the cognitive production during adolescence. We consider the cumulative model (4) and the augmented value added model (8) and three estimation methods: the OLS, family fixed effect and two-step estimation methods. The outcome variable, which is the cognitive ability of the child during adolescence, is measured by considering the three standardized test scores already described in Section 3, which are the Letter-Word Identification Score (LWS), the Passage Comprehension Score (PCS) and the Applied Problems Score (APS). We estimate these production models using the sibling sample (see Table A1 in the Appendix for some summary statistics of the variables used) and treating the three tests as repeated measures of the child's ability, so that our number of observations increase from 404 (the number of siblings) to 1212 (the number of siblings multiplied by the number of tests available for each child).[11] Both the value added and the augmented value added models include the same explanatory variables except for the lagged test, which is included only in the augmented model.

Our main coefficients of interest are the effects of time investments by the child and his/her mother during adolescence (child's and mother's time) and during childhood (child and mother lagged time), and we focus our discussion mainly on these four coefficients and on the coefficient of the lagged test, which is of interest in its own right. The lagged test coefficient

[11] We tested whether the cognitive production models estimated separately for the three tests have equal coefficients. The Chow test is equal to 1.411 (p-value 0.082), and we do not reject the hypothesis of equality of coefficients at significance level of 5%.

is a measure of the correlation between the contemporaneous and lagged test net of the explanatory variables and allows us to assess whether a bad test result today may imply a trap into low cognitive achievements for the child's future.

There are differences across different specifications and estimations, but two findings emerge clear from all models and estimations: (i) looking at time investments by the mother it seems that the mother's investment during childhood matters, while mother's investment during adolescence does not affect the cognitive ability during adolescence (see rows 2 and 4 in Table 4); (ii) looking at the effect of time investments by the child there is an opposite result, the child's investment during childhood matters less than the child's investment during adolescence (see rows 3 and 5 in Table 4). Notice that the mother's time investment on her child decreases from about 10 hours per week to 5 hours per week when children move from childhood to adolescence (see bottom panel in Table 1). This implies that children get more independence in deciding how to invest their time, hence the importance of their own time investments during adolescence in explaining their cognitive test results.

Looking at the estimation results for the augmented value added model (see columns 3, 4 and 5), another clear finding is that the lagged test is always very significant, suggesting a very high persistence in the test score results. Nevertheless, this persistence decreases from 0.528 to 0.352 when we control for the family fixed effects (see columns 3 and 4 in Table 4) and to 0.279 when we also control for the individual fixed effect (see column 5), suggesting that part of the persistence is explained by unobserved ability endowments.

Next, we discuss differences across our models and estimation methods and suggest which of our estimation results should be preferred. We are concerned with the potential omission of family characteristics and endowments, and for this reason we consider and compare the OLS and the family fixed effect estimations. Results seem to change when moving from the OLS to the family fixed effect estimation (compare columns 1 and 2, and columns 3 and 4 in Table 4) and this suggests that the specifications in columns 1 and 3 suffer from a variable omission problem.[12] Since we are concerned also with the possibility that mother's and child's time investments may depend on the past level of the child's cognitive ability, we consider the augmented value added model, which allows the investments to depend on the child's lagged test. Results seem to change when moving from the cumulative model to the augmented value

[12] We computed the Hausman tests and results confirm that the specifications with family fixed effects are more appropriate

added model estimated using OLS (compare columns 1 and 3 in Table 4), in particular the effects of the time investments generally attenuate. On the contrary, there are small changes when moving from the cumulative to the augmented value added model estimated using the family fixed effect estimation (see columns 2 and 4 in Table 4). This is possibly due to the fact that part of the dependence of the investments on the lagged cognitive ability is channelled through unobserved cognitive endowments, which are partly captured by the family fixed effects. To summarize our preference among the estimations considered so far (columns 1 to 4 in Table 4), we prefer the augmented value added with family fixed effects (see column 4 in Table 4) because we believe it provides more reliable results than the cumulative model and the augmented value added without family fixed effects.

The next question is whether considering the lagged test and family fixed effects is enough to control for all unobserved characteristics that are associated with the explanatory variables and relevant in explaining the cognitive tests. It is certain that family fixed effect estimation fails to control for unobserved individual abilities that differ between siblings. Since both cognitive tests measured during adolescence and during childhood are likely to depend on these individual abilities, we have an issue of endogeneity of the lagged cognitive test. But, as explained in Section 4, we can use a two-step estimation to take account of it. The results of this two-step estimation are reported in the last column of Table 4, where standard errors have been boostsrapped using 1,000 replications. These are our preferred results because the two-step estimation takes account of all our main econometric concerns, which are the potential dependence of time investments on past cognitive abilities, the problem of omission of unobserved family characteristics, and the endogeneity issue of the lagged test. The main difference in the results between columns (4) and (5) in Table 4 is an attenuation of the coefficient of the lagged test, and this confirms that the family fixed effect estimation presented in column (4) is inadequate to control for unobserved individual characteristics that differ between siblings. Nevertheless, we find that the coefficients of the time investments as well as the effects of all variables remain almost unaltered in size and statistical significance.

Table 4: Cognitive production model estimation results – Sibling sample

Dependent variable: standardized test scores (LWS, PCS, APS)					
	Cumulative OLS	Cumulative Family FE	Augmented Value Added OLS	Augmented Value Added Family FE	Augmented Value Added Two-step
Lag(test)			0.528***	0.352***	0.279***
			-0.023	-0.028	-0.044
Mother's time	-0.004	-0.007	0.003	0	-0.001
	-0.006	-0.007	-0.005	-0.007	-0.006
Child's time	0.022***	0.010*	0.022***	0.014***	0.013**
	-0.004	-0.005	-0.004	-0.005	-0.005
Lag(Mother's time)	0.009**	0.010*	0.010***	0.009*	0.010*
	-0.004	-0.005	-0.003	-0.005	-0.005
Lag(Child's time)	0.013**	0.007	0.005	0.005	0.005
	-0.005	-0.006	-0.004	-0.005	-0.006
Child age	-0.185	0.045	-0.631*	-0.476	-0.368
	-0.427	-0.411	-0.355	-0.384	-0.414
Child age sq.	0.004	-0.001	0.022	0.018	0.014
	-0.016	-0.016	-0.014	-0.015	-0.016
Male	-0.107*	-0.099	-0.02	-0.087	-0.092
	-0.055	-0.063	-0.046	-0.058	-0.262
Mother age	0.302***	-0.144	0.139**	-0.079	-0.002
	-0.07	-0.233	-0.058	-0.216	-0.002
Mother age sq.	-0.003***	-0.002	-0.001*	-0.002	-0.089
	-0.001	-0.002	-0.001	-0.002	-0.065
Birth order	-0.225***	0.011	-0.106***	-0.021	-0.014
	-0.037	-0.085	-0.031	-0.079	-0.088
Born 1982-1987	-0.051	1.587	-0.045	1.024	1.139
	-0.058	-1.026	-0.048	-0.953	-1.219
Constant	-5.081*	8.498	1.025	8.385	8.409
	-3.079	-8.426	-2.573	-7.815	-9.471
R-squared	0.126		0.396		
N. observations	1212	1212	1212	1212	1212
N. sibl. Groups		202		202	202
Sibl. correlation		0.918		0.86	
F test	16.88883	1.466	67.271	17.782	
p-value	0	0	0	0	

Standard Errors are in brackets and for the two-step estimation they are bootstrapped.
*p<0.10,**p<0.05,***p<0.01

Considering our preferred estimates (see column 5 in Table 4), an increase of 10 hours per week in the mother's time input during childhood seems to have an effect similar to an increase of 10 hours per week in the child's own time input during adolescence,[13] both changes lead to a rise of about 10-13% of a standard deviation of the cognitive test. The effect of decreasing children's time investments during adolescence of 10 hours per week is identical

[13] Mother's and child's time inputs during late childhood and adolescence are measured in a specific week when mother and child are interviewed, but we assume that this represents an average of these time inputs.

to the effect of having a mother working full-time and using child care during one year on children's cognitive tests measured in the preschool period, as found by Bernal (2008) using National Longitudinal Survey of Youth 79 (NLSY79) in USA. A similar effect is found also in Bernal & Keane (2011) when evaluating the effect of an increase of one year in full time child care using again the NLSY79, but considering exogenous changes in the work/child care decisions caused by the introduction of new welfare policy rules for single mothers in USA.

In conclusion, the main results of our empirical analysis may be summarized in following three main points. First, the quality time children spend on their own during adolescence explains their test scores much more than the quality time the mother's spends with them during adolescence. Second, time inputs during childhood by the mother are relevant to explain adolescents' test scores, while children's own time investment during childhood are not as important as the quality time they spend with their mother. Third, there is a large persistence of the test score and this implies that, if a child obtains a bad result on a test during childhood, there is a strong probability that she will get again a bad result during adolescence. This is obviously in part explained by innate individual abilities. In fact, once we control for the unobserved abilities using individual fixed effect estimation, we find a smaller effect of the lagged test on the contemporaneous test.

6. Sensitivity analysis

In this section we report our sensitivity analysis, which allows us to check the robustness of our empirical results to (i) the inclusion of father's time investments, (ii) the extension of the sample to non-intact families, (iii) the change of the child's age range and (iv) the adoption of specifications which allow for a non-linear effect of the time inputs on the child's cognitive skill. For each of the four sensitivity analysis we report our coefficients of interests, i.e., the effects of contemporaneous and lagged time inputs, and we examine how these "core" coefficients estimates behave. We carry out this analysis only for our preferred estimation, i.e., the two-step estimation of the augmented value added model.

We begin by considering the inclusion of fathers' time inputs to our original production function. In the first column of Table 5 we report, for comparison, the estimates obtained by considering the mother's time inputs (which were already reported in the last column of Table

4), while in the second column we show the estimates obtained by replacing the mother's time inputs with the father's ones. Finally, in the last column of Table 5 we report the results computed by using both mother's and father's time inputs. The effect of child's time inputs remains the same across specifications which include mother's time, father's time and both parents' time. The coefficients of the lagged test and the lagged mother's time are also almost unaffected. As discussed in the Section 2, only a few studies have analyzed both parents' inputs since most datasets include only limited information about fathers. The empirical findings are mixed, some studies show a small impact while others show a positive impact. The differences depend on the specifications used, on the test scores considered as well as the age of the child. Chen (2012) finds no significant impact on reading test scores but only on math test scores. Del Boca et al. (2013) show that fathers' time impact on reading test score is low when the child is young and increases when the child grows up.

Secondly, we consider family composition. In our analysis, we have focused on families where children live with their biological parents. We now extend the analysis to all families where at least the mother is present and we include divorced, widowed and lone mothers. In many countries, the proportion of children growing up with both biological parents has declined dramatically over time. In our extended sample we find that 16.5% of children live in households where the biological father is absent. Sociological studies show that living in some types of non-intact families is more difficult for children than living in others, and that growing up with a divorced or never-married mother seems to be associated with lower educational achievements, while growing up with a widowed parent is not McLanahan, 1997). Our results, reported in Table 6, show that our coefficients of interest do not change across different family types. More precisely, the estimates obtained by considering only families with both biological parents (first column in Table 6) are very similar to the ones obtained from the extended sample which includes divorced, widowed and lone mothers (second column in Table 6).

Table 5: Robustness check: Child, mother, and father investments.

Dependent variable: standardized test scores (LWS, PCS, APS)
Augmented value added model. Two step estimation.

	Mother	Father	Both parents
Lag(test)	0.279***	0.279***	0.279***
	-0.044	-0.044	-0.045
Mother's time	-0.001		-0.004
	-0.006		-0.008
Father's time		0.002	0.003
		-0.007	-0.009
Child's time	0.013**	0.014***	0.013**
	-0.005	-0.005	-0.005
Lag(Mother's time)	0.010*		0.012**
	-0.005		-0.006
Lag(Father's time)		0	-0.006
		-0.006	-0.007
Lag(Child's time)	0.005	0.003	0.005
	-0.006	-0.005	-0.006
Constant	8.409	9.723	7.331
	-9.471	-8.449	-8.731
N. observations	1212	1212	1212

Boostrapped standard errors in brackets
*p<0.10,**p<0.05,***p<0.01
Controls include: Child's age, Child's age sq., Male, Mother's age, Mother's age sq., Birth order, Born 1982-1987.

Table 6: Robustness check: Family composition

Dependent variable: standardized test scores (LWS, PCS, APS)
Augmented value added model. Two step estimation

	Both biological parents (our sibling sample)	All families
Lag(test)	0.279***	0.267***
	-0.044	-0.038
Mother's time	-0.001	0
	-0.006	-0.005
Child's time	0.013**	0.015***
	-0.005	-0.005
Lag(Mother's time)	0.010*	0.009*
	-0.005	-0.005
Lag(Child's time)	0.005	0.007
	-0.006	-0.005
Constant	8.409	11.441
	-9.471	-7.791
N. observations	1212	1452

Boostrapped standard errors in brackets
*p<0.10,**p<0.05,***p<0.01
Controls include: Child's age, Child's age sq., Male, Mother's age, Mother's age sq., Birth order, Born 1982-1987.

Third, we analyze different age groups, aged 10-14 and 12-16 respectively rather than 11-15. As we discussed above the importance of the impact of child's time tends to grow with the age of the child, while the importance of the impact of the family tends to decline with the age of the child. Our results, reported in Table A4 in the Appendix, confirm this hypothesis and show that the coefficient of contemporaneous child's time is not statistically significant for younger children (10-14), but becomes statistically significant for older children (12-16). Moreover, the coefficient of lagged mother's time is smaller, although not statistically different, for older children.

Finally, in Table A5 in the Appendix, we introduce some non-linearities in the effect of mother and child's time inputs. We estimate three different specifications: (1) a model with switching time inputs' coefficients with switching threshold given by the corresponding time input median, (2) a model with an additional dummy variable for each time input, which takes value one when the time input is zero and zero otherwise, (3) a model where all time inputs are expressed in logarithms (see respectively first, second and third columns in Table A5). The first specification allows the effect of each time input to be different for values that are below and over the median. Results in the first column of Table A5 suggest that each of the time inputs has a coefficient that does not vary significantly below and over the median, so that our linear specification is not rejected. The second model allows for a discontinuity at zero so that when a time input is zero its effect is not imposed to be zero. Results in the second column in Table A5 show that the dummy variables indicating zero time inputs have coefficients which are not significantly different from zero, suggesting again that our linear specification is not rejected. Lastly, the third model allows for a further form of non-linearity of the partial effects by resorting to the log transformation of the various time input variables. In this specification the estimated inputs' coefficients are interpretable as semi-elasticities, and this explains their observed change (see last column in Table A5). However, it can be noticed that their magnitude is again coherent with our benchmark model estimation results.

7. Conclusions

While a large literature has focused on the impact of parental time on child outcomes, very little is still known on the impact of children's own time investments in their development process. This paper represents to our knowledge the first empirical assessment of the effect of time investment by the children themselves on their cognitive skills in the adolescence period.

We model the cognitive production function using an augmented value added specification and we account for different sources of endogeneity that typically undermine the identification of the inputs' coefficients. First, we are able to control for the endogeneity of parents' and children's time investments arising from unobserved household-specific inputs by way of family fixed effect estimation. Second, by considering the lagged cognitive test among the inputs of the production model, we allow the choice of time inputs to depend on the past child cognitive achievements. Finally, the endogeneity of the lagged test, which is caused by its dependence on the unobserved individual-specific skill endowment, is dealt with by applying a child-specific individual effect estimation, which makes use of the multiplicity of cognitive tests available in our data.

We show that during childhood the time inputs by the mother matter more than the time inputs by the children. On the contrary, the time investments by children during adolescence affect their test scores much more than the time inputs by their mother. Our results have important policy implications. Indeed, they suggest that a way to improve cognitive abilities of adolescents is by influencing their time allocation decisions and their investments in formative activities. However, there are other important factors which can affect adolescents' time investments, such as schooling quality, parenting style and peer effects, whose examination we leave for future research.

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Appendix

Table A1: Summary statistics – Main sample

Variable	Mean	Std. Dev.
Tests		
LWS	105.842	16.792
PCS	104.055	14.956
APS	107.135	15.149
Lag(LWS)	109.649	16.53
Lag(PCS)	110.299	14.261
Lag(APS)	110.745	16.94
Time inputs		
Mother's time input	5.463	5.197
Lag(Mother's time input)	9.472	7.082
Father's time input	4.078	5.045
Lag(Father's time input)	5.996	5.943
Child own time input	5.123	6.859
Lag(Child own time input)	4.076	5.149
Control variables		
Age	13.025	1.41
Mother's age	41.397	5.276
Male	0.479	0.5
Birth order	1.886	0.847
Born 1982-1987	0.528	0.5
Number of observation	726	

LWS: Letter Word Identification Score
PCS: Passage Comprehension Score
APS: Applied Problem Score

Table A2: Summary statistics – Sibling sample

Variable	Mean	Std. Dev.	Difference	
			Main sample [a]	All families [b]
Tests				
LWS	107.606	16.266	1.765*	1.482
PCS	105.255	14.686	1.2	1.561
APS	108.973	14.914	1.838**	1.481
Lag(LWS)	110.906	16.966	1.257	1.317
Lag(PCS)	111.196	14.318	0.897	1.056
Lag(APS)	112.347	16.806	1.601	1.83
Time inputs				
Mother's time input	5.253	4.918	-0.21	0.033
Lag(Mother's time input)	9.711	6.951	0.239	0.539
Father's time input	4.096	4.812	0.017	0.368
Lag(Father's time input)	6.067	5.875	0.069	0.702*
Child own time input	5.148	6.458	0.025	0.205
Lag(Child own time input)	4.201	5.265	0.125	0.296
Control variables				
Age	12.998	1.403	-0.27	-0.231
Mother's age	41.354	4.912	-0.043	0.751**
Male	0.475	0.5	-0.004	-0.01
Birth order	1.839	0.785	-0.047	-0.026
Born 1982-1987	0.525	0.5	-0.003	-0.041
Number of observations	404			

[a] Difference in means across Sibling sample and Main sample
[b] Difference in means across Sibling sample and All families sample (including single mothers)
*, **, *** : two sided t test for H_0: Difference=0 statistically significant at 10%, 5%, 1% level

Table A3: Father's time input composition

	Weekly time (hours)							
	Child's age range 6-10*				Child's age range 11-15**			
	Mean	SD	Min	Max	Mean	SD	Min	Max
Father's time inputs								
Total time	6	5.94	0	45.92	4.08	5.04	0	36.25
Reading	0.15	0.58	0	6.67	0.06	0.58	0	12.33
Homework	0.05	0.46	0	7.5	0.09	0.78	0	11.17
Playing	0.99	2.49	0	23.33	0.35	1.65	0	25.67
Talking	0.23	0.83	0	7.73	0.33	1.1	0	13.25
Arts and craft	0.13	1.38	0	33.75	0.05	0.6	0	11
Sport	0.44	1.6	0	15	0.17	1.13	0	16.5
Attending performances	0.04	0.48	0	7.5	0.08	0.73	0	13.33
Attending museums	0.02	0.39	0	9.5	0	0	0	0
Religious activity	0.6	1.84	0	15.27	0.55	1.92	0	20
Meals	3.04	2.8	0	20.5	2.34	2.74	0	21.75
Personal care	0.31	1.16	0	15.25	0.07	0.47	0	6

Number of Observations: 726
*years1997-2002, pooled
**years 2002-2007, pooled

Table A4: Robustness check: Different age range samples

Dependent variable: standardized test scores (LWS, PCS, APS)
Augmented value added model. Two steps estimation.

	Child's age 10-14	Child's age 12-16
Lag(test)	0.269***	0.302***
	-0.052	-0.048
Mother's time	0.021*	0.012
	-0.013	-0.009
Child's time	0.011	0.009*
	-0.007	-0.005
Lag(Mother's time)	0.016**	0.014**
	-0.007	-0.006
Lag(Child's time)	0.002	0.002
	-0.01	-0.007
N. observations	906	1068

Bootstrapped standard errors are in brackets and are bootstrapped
*p<0.10,**p<0.05,***p<0.01
Controls include: Child's age, Child's age sq., Male, Mother's age, Mother's age sq., Birth order, Born 1982-1987 dummy.

Table A5: Robustness check: Non-linearities – Sibling sample

Dependent variable: standardized test scores (LWS, PCS, APS) Augmented value added model. Two steps estimation.	Switching coeff for time < median	Including dummies for zero time	Time inputs in logs
Lag(test)	0.0279	0.279***	0.279***
	-0.043	-0.045	-0.043
Mother's time	0	0	0.005
	-0.007	-0.007	-0.041
Mother's time if below the median	0.021		
	-0.033		
Dummy for zero mother's time		0.025	
		-0.102	
Child's time	0.014**	0.011*	0.075**
	-0.005	-0.006	-0.033
Child's time if below the median	-0.009		
	-0.071		
Dummy for zero child's time		-0.051	
		-0.085	
Lag(Mother's time)	0.010*	0.010*	0.084
	-0.006	-0.005	-0.053
Lag(Mother's time) if below the med	0.002		
	-0.014		
Dummy for zero Lag(Mother's time)		-0.058	
		-0.19	
Lag(Child's time)	0.007	0.003	0.024
	-0.006	-0.006	-0.033
Lag(Child's time) if below the med	0.042		
	-0.05		
Dummy for zero Lag(Child's time)		-0.044	
		-0.095	
Constant	9.144	8.951	9.31
	-9.433	-9.243	-9.144
Number of observations	1212	1212	1212

Bootstrapped standard errors are in brackets
*p<0.10,**p<0.05,***p<0.01
Controls include: Child's age, Child's age sq., Male, Mother's age, Mother's age sq., Birth order, Born 1982-1987 dummy.