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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. Information on how children invest their time separately from parents is probably little informative for babies and toddlers, but it becomes more and more important in later stages of life, such as adolescence, when children start to take decisions independently. By using the Child Development Supplement of the PSID (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. Our results are obtained accounting for potential unobserved child's and family's endowments and are robust across several specifications and samples, e.g. considering and not considering father's investments and non-intact families.

JEL Classification: J13, D1

Keywords: time-use, cognitive ability, child development, adolescence

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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 and Heckman (2003) and Cunha and Heckman (2008) are among the few papers developing 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 assessment of the role played by self investments of adolescents in shaping their cognitive development, adapting the production function during adolescence to consider inputs by the children themselves. We model the cognitive production function by way of an augmented valued added specification, where cognitive ability depends on a set of contemporaneous and lagged inputs and on lagged cognitive ability (see Todd and 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 and Heckman 2003, Ermisch and Francesconi 2005, Haveman and Wolfe 1995). Since most socio-economic surveys lack appropriate measures of parental time, most studies have been forced to use proxy measures such as mothers' employment (Bernal 2008, Todd and Wolpin 2007, Liu et al 2010, Bernal and Keane 2011). A more accurate measure of the time investments in children is provided by the time diary surveys. The time diary surveys usually contain detailed information on the time children spend in different activities with the mother, the father and other adults, but only few papers have used time diaries to measure time investments in children. Among these few exceptions are Hsin (2007, 2009) Carneiro and Rodriguez (2009) and Del Boca et al. (2010), 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 and 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 (2010) distinguish between the time the child spends with mother and the time she spends with 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.[1] 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 behavioural 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)

[1] 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 consider adult children who are already at the university.

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 investment by children.

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. Two examples are given by Fiorini and Keane (2011) and Agee et al (2011). Fiorini and Keane (2011) rely on 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. Agee et al (2011) use the National Longitudinal Survey of Youth–Child Sample to estimate a household's production model for multiple child's outcomes and include among the set of home inputs the time children spend reading, doing homework, watching television and staying with family. Here, the choice of definition of time investment is motivated by the survey originating the dataset, which does not contain time diaries but just recall questions about daily time use in some specific activities. This makes it also impossible for the authors to distinguish between the time the child spends on her own and the time she spends actively supervised by an adult. Several 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 have a positive effect on children's achievement, measured by vocabulary, reading comprehension and verbal fluency (Anderson et al 1988; Taylor et al 1990; Cunningham and Stanovich, 1991 and 1993). For instance, Searls et al (1985) evaluate the effects on reading abilities of 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.

Studying children time investment and its impact on their cognitive outcomes may have important implications for public policy. Empirical evidence shows that the effect of parental investments on cognitive skills reduces rapidly across age (see Cunha and Heckman 2006). In particular, looking at mothers' and fathers' time investments, Del Boca et al (2010) 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, since the time investment by the children themselves is presumably more important during adolescence, a policy directed at improving the time use of adolescents could be a way to improve adolescents' cognitive developement.[2]

3 Data and preliminary evidence

Our analysis relies on the Child Development Supplement (CDS), funded by the National Institute of Child Health and National Development (NICHD). The CDS covers a maximum of two children for a subsample of households interviewed in the Panel Study of Income Dynamics.[3] 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 char-

[2]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 parent time investments are not directly affecting adolescents' cognitive skills, they may affect them indirectly through the transmission of time use habits.

[3]The Panel Study of Income Dynamics is a USA longitudinal survey of a nationally representative sample of individuals and families, started in 1968 with a sample of 4800 families. It collects yearly individual information on economic, demographic, sociological, and psychological variables and well-being.

acteristics. 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 a nd 15 and living with both biological parents. To avoid small sample size issues, we pool two cohorts of children, 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.[4] 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.[5] 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).[6] 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 (2010) 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.

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

[4] 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.

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

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

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 kindergarden and primary school has a positive effect on school performance.

In the upper part of Table 1 we display 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 rise (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. Fathers spend 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 increase 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 kraft	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 kraft	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	13.33
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								
*years1997-2002, 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.[7] 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 cognitives measures considered during the adolescence period.

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

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
St. 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^
St. Error		1.254	1.112	1.131
Two sided t test for H_0: Difference=0				
^,*, **, *** statistically significant at 15%, 10%, 5%, 1% level respectively				

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 in 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.

	Obs	LWS Average	PCS Average	APS Average
Contemporaneous input (age 11-15)				
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***
St. 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	106.286
Difference		3.675***	2.994***	2.300**
St. Error		1.285	1.145	1.162

Two sided t test for H_0: Difference=0

*, **, *** statistically significant at 10%, 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 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

$$Y_{ijt} = F_t(\mathbf{X}_{ijt}, \mathbf{X}_{ijt-5}, \mathbf{X}_{ijt-10}, \mu_{ij}) \tag{1}$$

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, $X^S_{ijt}, \mathbf{X}'_{ijt} = [X^{C\prime}_{ijt}, X^{F\prime}_{ijt}, X^{S\prime}_{ijt}]$;
- the corresponding vector of inputs during late childhood (5 years earlier), $\mathbf{X}'_{ijt-5} = [X^{C\prime}_{ijt-5}, X^{F\prime}_{ijt-5}, X^{S\prime}_{ijt-5}]$;

- the corresponding vector of inputs during early childhood (10 years earlier), $\mathbf{X}'_{ijt-10} = [X^{C\prime}_{ijt-10}, X^{F\prime}_{ijt-10}, X^{S\prime}_{ijt-10}]$;
- her cognitive endowment μ_{ij}.

This 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 and Wolpin 2003 and 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

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

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

$$Y_{kijt} = \beta_0 + \beta_1 \mathbf{X}_{ijt} + \beta_2 \mathbf{X}_{ijt-5} + \beta_3 \mathbf{X}_{ijt-10} + \mu_{ij} + \epsilon_{kijt}, \tag{3}$$

or more explicitly as

$$\begin{aligned} Y_{kijt} \;=\; & \beta_0 + \beta_1^C X^C_{ijt} + \beta_1^F X^F_{ijt} + \beta_1^S X^S_{ijt} + \beta_2^C X^C_{ijt-5} + \beta_2^F X^F_{ijt-5} \\ & + \beta_2^S X^S_{ijt-5} + \beta_3^C X^C_{ijt-10} + \beta_3^F X^F_{ijt-10} + \beta_3^S X^S_{ijt-10} + \mu_{ij} + \epsilon_{kijt}, \end{aligned} \tag{4}$$

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 and 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^C_{ijt-10}, 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.

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 and 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 $i\prime$ and differentiating the cumulative model produces

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

where DA_{ijt} denotes the difference of the variable A between sibling i and $i\prime$.[8] Note that, since we are assuming that siblings have equal school inputs in early childhood, late childhood and adolescence and that inputs during early childhood by schools, families and children themselves do not vary between siblings, differences in school inputs and in early child inputs cancels out from the model. Furthermore, 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 $D\mu_{ij}^F$ 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 valued added model* (as defined by Todd and Wolpin 2007)

$$Y_{kijt} = \beta_0 + \beta_1 \mathbf{X}_{ijt} + \beta_2 \mathbf{X}_{ijt-5} + \rho Y_{ijt-5} + \mu_{ij} + \epsilon_{kijt}. \quad (6)$$

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

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

[8] 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.

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_ϵ^2, 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.[9] By replacing the unobserved latent ability Y_{ijt-5} with the observed Y_{kijt-5}, the valued added model becomes

$$Y_{kijt} = \beta_0 + \beta_1 \mathbf{X}_{ijt} + \beta_2 \mathbf{X}_{ijt-5} + \rho Y_{kijt-5} + \mu_{ij} + u_{kijt}, \tag{8}$$

where $u_{kijt} = \epsilon_{kijt} - \rho\epsilon_{kijt-5}$. 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

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

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

$$\frac{Cov(\epsilon_{kijt}, \epsilon_{kijt-5})}{\sqrt{Var(\epsilon_{kijt-5})Var(\epsilon_{kijt})}} = \frac{Cov(\epsilon_{kijt}, \epsilon_{kijt-5})}{Var(\epsilon_{kijt-5})} = \rho. \tag{9}$$

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,

$$\begin{aligned} DY_{kijt} &= \beta_1^C DX_{ijt}^C + \beta_1^F DX_{ijt}^F + \beta_2^C DX_{ijt-5}^C + \beta_2^F DX_{ijt-5}^F \\ &\quad + \rho DY_{kijt-5} + D\mu_{ij}^C + Du_{kijt}. \end{aligned} \tag{10}$$

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

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

test, DY_{ijt-5}, and the (sibling differenced) child specific endowment component, $D\mu^C_{ij}$. 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. Under the assumptions stated above, it can be proven that the individual fixed effect estimation converges to

$$plim \rho_{IndFE} = \frac{Cov(\epsilon_{kijt}, \epsilon_{kijt-5})}{Var(\epsilon_{kijt-5})} = \rho. \tag{11}$$

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 $\beta^C_1, \beta^F_1, \beta^C_2$ and β^F_2. Nevertheless, we can replace ρ with its estimate in

$$\begin{aligned} DY_{kijt} - \rho DY_{kijt-5} &= \beta^C_1 DX^C_{ijt} + \beta^F_1 DX^F_{ijt} + \beta^C_2 DX^C_{ijt-5} \\ &\quad + \beta^F_2 DX^F_{ijt-5} + D\mu^C_{ij} + Du_{kijt}, \end{aligned} \tag{12}$$

and use family fixed effect estimation to produce estimates for the coefficients $\beta^C_1, \beta^F_1, \beta^C_2$ and β^F_2. Thanks to this 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 channelled 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 and Heckman (2008) use multiple measures of tests and inputs, which are available in their dataset, 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 impose 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.

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 valued 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 stadardized 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).[10] 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 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 seems to change when moving from the OLS to the family fixed effect estimation (compare columns 1 and 2,

[10]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%.

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.[11] 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 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 because 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 valued added with family fixed effects (see column 4 in Table 4) because we think 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 boostrapped 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 remaining variables remain almost unaltered in size and statistical significance.

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

Table 4. Cognitive production model estimation results - Sibling sample.

Dependent variable: standardized test scores (LWS, PCS, APS)					
	Cumulative	Cumulative	Augmented Value Added	Augmented Value Added	Augmented Value Added
	OLS	Family FE	OLS	Family FE	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	0.000	-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	-0.020	-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
	(0.070)	(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		0.860	
F test	16.88883	1.466	67.271	17.782	
p-value	0.000	0.000	0.000	0.000	

Standard Errors are in brackets and for the two-step estimation they are bootsrapped.
*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, 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 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 and 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 reduced 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 remain 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 (2010) show that fathers' time impact on reading test score is low when the child is young and increases when the child grow 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 associated with poorer outcomes for children (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)		0.000	-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	0.000
	(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

Bootstrapped 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 analyse different age groups, aged 10-14 and 12-16 respectively. 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 assumption and show that the coefficients 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 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 allows 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 input by the mother matters 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 input by their mother. By spotting a channel of public policy intervention in the adolescent period, 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 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.	Min	Max
Tests				
LWS	105.842	16.792	46	183
PCS	104.055	14.956	37	187
APS	107.135	15.149	64	166
Lag(LWS)	109.649	16.530	54	184
Lag(PCS)	110.299	14.261	63	187
Lag(APS)	110.745	16.940	49	158
Time inputs				
Mother's time input	5.463	5.197	0	35.417
Lag(Mother's time input)	9.472	7.082	0	40.417
Father's time input	4.078	5.045	0	36.25
Lag(Father's time input)	5.996	5.943	0	45.917
Child own time input	5.123	6.859	0	41.25
Lag(Child own time input)	4.076	5.149	0	30.917
Control variables				
Age	13.025	1.410	11	15
Mother's age	41.397	5.276	27	58
Male	0.479	0.500	0	1
Birth order	1.886	0.847	1	5
Born 1982-1987	0.528	0.500	0	1
Number of observations	726			

Table A2. Summary statistics - Sibling sample

Variable	Mean	Std. Dev.	Min	Max
Tests				
LWS	107.606	16.266	53	174
PCS	105.255	14.686	59	143
APS	108.973	14.914	66	166
Lag(LWS)	110.906	16.966	54	184
Lag(PCS)	111.196	14.318	63	187
Lag(APS)	112.347	16.806	56	156
Time inputs				
Mother's time input	5.253	4.918	0	33.417
Lag(Mother's time input)	9.711	6.951	0	37.75
Father's time input	4.096	4.812	0	35.917
Lag(Father's time input)	6.067	5.875	0	39.25
Child own time input	5.148	6.458	0	36.5
Lag(Child own time input)	4.201	5.265	0	30.917
Control variables				
Age	12.998	1.403	11	15
Mother's age	41.354	4.912	27	54
Male	0.475	0.500	0	1
Birth order	1.839	0.785	1	4
Born 1982-1987	0.525	0.500	0	1
Number of observations	404			

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 kraft	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
	(0.010)	(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	0.000	-0.000	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 zeor Lag(Mother's time)		-0.058	
		(0.190)	
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		
	(0.050)		
Dummy for zero Lag(Child's time)		-0.044	
		(0.095)	
Constant	9.144	8.951	9.310
	(9.433)	(9.243)	(9.144)
Nunber of observations	1212	1212	1212

Bootstrapped 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 dummy.

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