The Effect of Home Computer Use on Children's Cognitive and Non-Cognitive Skills

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Abstract

In this paper we investigate the effect of using a home computer on children's development. In most OECD countries 70% or more of the households have a computer at home and children use computers quite extensively, even at very young ages. Yet, little is known about the effect of computer usage on children's cognitive and non-cognitive skills. Time spent using a computer can affect skills in different ways: because of the way children use the computer, i.e. content, because computer time inevitably displaces other activities, and because most software requires interaction and is therefore intellectually stimulating. We use data from the Longitudinal Study of Australian Children (LSAC), which follows an Australian cohort born in 2000. Skills and computer usage information is collected when children are approximately 5 and 7 years old. For cognitive skills, our results indicate that computer time has a positive effect. The effect is large relatively to other inputs, such as child care, and is not shared by other media devices, such as television and video games which instead show a negative effect. For the non-cognitive skills the evidence is more mixed, with the direction of the effect depending on the score and the age of the children. We test the robustness of our results by comparing OLS, IV and Value Added estimators. Generally, the IV estimates are larger and the Value Added estimates lower than the OLS ones. However the pattern of the results is quite consistent.

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1 Introduction

In the last decade a number of papers have stressed that educational and labor market outcomes are largely pre-determined by the cognitive and non-cognitive skills accumulated during early childhood. Keane and Wolpin (1997, 2001), Cameron and Heckman (1998, 2001) have found that in the US individual educational decisions are mainly driven by cognitive skills such as maths and verbal skills. Those with good skill endowments by age 16 are much more likely to enrol and complete college education. Financial constraints are either not binding or most individuals manage to offset them by working part-time and borrowing. Their results suggest that policies targeting educational attainment or educational disparities between Black, Hispanic and White youth must act on these skill inputs to be effective. Heckman, Stixrud, and Urzua (2006) find that a low-dimensional model of cognitive and non-cognitive abilities explains a diverse array of outcomes such as schooling choices, wages, employment, work experience, choice of occupation but also a variety of adolescent risky behaviors such as criminality, cigarette smoking and alcohol use. Cunha, Heckman, Lochner, and Masterov (2006) review the evidence on the life cycle of human skill formation. They conclude that ability gaps in both cognitive and non-cognitive skills across individuals and across socioeconomic groups open up early in the life cycle and IQ deficits need to be addressed at very early ages for interventions to be effective.

Given this evidence, there is a growing interest in estimating the skills production function. Researchers are trying to uncover the main inputs and their time varying effect (see Todd and Wolpin (2003) and Cunha and Heckman (2007) for a discussion). However estimating the causal effect of these inputs is difficult because all sorts of endogeneity problems might lead to inconsistent estimates and economists have mainly focused on a few inputs that are either very important or for which experimental designs are available. To mention only a few recent studies that have looked at the determinants of math and reading achievements, Rivkin, Hanushek, and Kain (2005) analyze the effect of teacher quality, Dahl and Lochner (2005) and Belley and Lochner (2007) estimate the effect of parental income, Bernal and Keane (2008) and Berlinski, Galiani, and Manacorda (2008) evaluate the effect of respectively child care and pre-school while Gentzkow and Shapiro (2008) identify the effect of pre-school television exposure.

The objective of this paper is to investigate the effect of using a computer at home. Computers are a relatively new input in the production function. Figure 1 shows OECD data on home computer access in a few selected countries. [1] There is a clear upward trend. Since 2005, in all the countries 70% or more of the households had a computer at home and this proportion is likely to rise further. As we show below, children use home computers quite extensively. Yet, little is known about the effect of computer usage on children's cognitive and non-cognitive skills.

Psychologists have long investigated the effect of time spent in front of the television on children's development, see Schmidt and Anderson (2007) for a review, and are now shifting their attention to computers, see Subrahmanyam, Greenfield, Kraut, and Gross (2001). Even though computers and TV are different media devices, understanding why TV time can have an effect on children's skills is a useful starting point to analyze the effect of computer time. There are three main theories in psychology. The first theory emphasizes the effect of TV content, that is what matters is what children watch and not TV time per se. On the one hand, this theory states that educational programs can have a positive effect on skills. On the other hand, if children watch mostly cartoons or general entertainment programs, TV would have no impact. The second theory points at the time allocation problem. Children, like adults, have a limited time endowment. The more time is spent watching TV, the less time is available for other activities. If TV time displaces other educational or social activities then it might have an effect even irrespectively of what children watch. The third theory points at the passive nature of television. Viewing requires little overt behavior, programs are visually explicit and require little visual imagination, and the medium is not interactive. As a result children might become intellectually passive. While we refer the reader to section 2 for a more complete review of the literature, we anticipate that

[1] Data for the USA is available for only a few years.

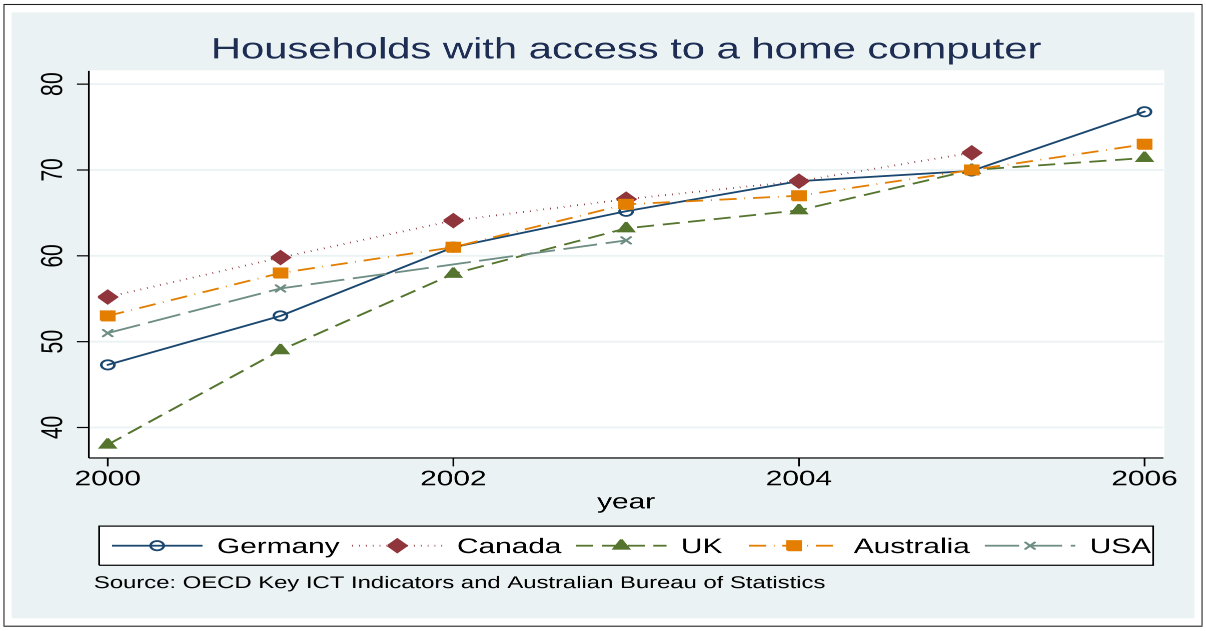

Figure 1: Household Home Computer Access

psychology studies conclude that the effect of watching TV strongly depends on the content of the programs watched (educational programs having a positive effect) and on the socio-economic status of the parents (children with low status parents benefiting more from TV), the latter reflecting the quality of those activities displaced by TV time. Computers and TV share some similarities but there are also major differences. Computers imply more freedom with respect to content, since there is a very large variety of software or internet content to choose from. Computers are also more interactive than TV, with most software requiring continuous inputs from the users. Still, most of the above discussion can be extended to computer time. Content can matter, other activities will be displaced by computer time, and computer use can be intellectually challenging (rather than intellectually passive).

In this paper we use the Longitudinal Study of Australian Children (LSAC) data, which follows an Australian cohort born in 2000. Data for this cohort were collected in two surveys (2004 and 2006) when children were aged 4/5 and 6/7 years old. The advantage of this data lies in its longitudinal nature, coupled with information about cognitive and non-cognitive test scores and information on computer access. In particular information was collected not only on whether the child had access to a computer at home, but also on the number of hours he/she would use the computer on a typical weekday and weekend. The LSAC data shows that by the age of 7 around 88% of the children had access to a computer at home. This is an even larger fraction than the 70 % reported in figure 1, probably due to the fact that these children had young parents who are more likely to use modern technologies. From these data it also emerges that the average child with access to a computer spends 3 and a half hours in front of a computer every week. Children also make extensive use of other devices spending 13 hours watching TV/DVD's and 3 and a half hours playing with video game consoles such as PlayStation, XBox and Nintendo every week. If we are interested in the skill production function we can not neglect the importance of these inputs given that they absorb a considerable amount of time. Here we mainly focus on computer use though we also try to shed some light on the effect of TV/DVD's and video game use. We look at both cognitive and non-cognitive skills. Both types of skills might be affected by the content (educational software, games, emailing or messaging, other internet use) but also by the displaced activities. If, for instance, computer time displaces reading books or time spent on homework, cognitive skills might be affected. Similarly, if computer time displaces social activities, with parents or other children, non-cognitive skills could be influenced.

Previous research has focused on the effect of TV on skills, of computers in schools or on the effect of a home computer on high school completion. Our paper contributes to the existing human capital literature by focusing on the effect of home computer use on early childhood cognitive and non-cognitive skills. To our knowledge no other economic study has tried to address this question so far.

In the remaining of the paper we first discuss the skills production function and the assumptions needed to identify the causal effect of computer use on cognitive and non-cognitive skills. We rely on a rich set of controls available in the LSAC, and assess the robustness of our results by comparing alternative estimators. Our results indicate that children using computers are more likely to score high in cognitive skill tests but less well in terms of non-cognitive skills. Computer use matters mainly during the weekend, and the effects are larger for girls and for children with highly educated parents.

The paper unfolds as follows: In section 2 we review the main findings of the computer literature. Section 3 introduces the skill production function and then discusses the identification of the parameter of interest. Section 4 presents the cohort data that we use. Section 5 presents our findings. Section 6 concludes.

2 Literature

The literature evaluating the impact of computer access and use on children's outcomes is still quite limited, probably due to the fact that computers entered schools and houses on a large scale only in the last 10 to 15 years. In this section we give a short summary of those studies evaluating the effect of computer use on labor market outcomes, educational attainment and cognitive skills.

2.1 Effect of Computer use on Labor Market Outcomes

Krueger (1993) uses Current Population Survey data to examine whether workers who use a computer at work earn a higher wage rate than otherwise similar workers who do not use a computer at work. Given the cross-section data, he estimates the causal effect through OLS where identification relies on a rich set of controls, including 2 digits occupational sectors. Estimates suggest that workers who use computers on their job earn 10 to 15 percent higher wages.

DiNardo and Pischke (1997) revisit Krueger's analysis and investigate whether his estimates reflect a true return to computer skills or just selection: i.e. higher wage workers use computers on their jobs. They do so using three large cross-sectional surveys from Germany. Like in Krueger's paper, they estimate an OLS model where identification relies on a rich set of controls. They find that the estimated wage differential associated with computer use in Germany is very similar to the U. S. differential. However, they also find large differentials for on-the-job use of calculators, telephones, pens or pencils, or for those who work while sitting down. They conclude that these returns to office tools, including computers, are probably driven by substantial selection.

2.2 Effect of Computer use on Educational Attainment

Schmitt and Wadsworth (2006) explore the link between ownership of a home computer at ages 15 and 17 and subsequent educational attainment in the principal British school examinations taken at ages 16 (GCSEs) and 18 (A-levels). Using the British Household Panel Survey (BHPS), they estimate the causal effect using a probit model where identification relies on a rich set of controls such as household income, mother and father's education, mother and father's age and number of dependent children living in the household. The data show a significant positive association between PC ownership and the qualifications obtained. The frequency of PC use also appears to be weakly correlated with positive educational outcomes at age 16.

Beltran, Das, and Fairlie (2006) look into the relationship between computer ownership and high school graduation in the US, using recent panel data from matched CPS files and the NLSY97. Using a probit model with a rich set of controls they find that home computers are associated with a 6-8 percentage point higher probability of graduating from high school. They also estimate a bivariate probit model for the joint probability of computer ownership and high school graduation using parental use of the Internet at work and the presence of another teenager in the household as instruments. The bivariate probit leads to coefficient estimates that are similar to the original probit estimates, although statistically insignificant.

2.3 Effect of Computer use on Skills

Angrist and Lavy (2002) assess the short-run consequences of increased computer-aided instruction (CAI) technology in Israeli schools. The causal effect is estimated using an OLS model and a 2SLS where the IV is given by an Israeli Government program that funded a large-scale computerization effort in many elementary and middle schools. The schools that received support were more likely to use CAI. Their results do not support the view that CAI improves learning, at least as measured by pupil test scores. They find a consistently negative and marginally significant relationship between the programme induced use of computers and 4th grade Maths scores. For other grades and subjects, the estimates are not significant, though also mostly negative.

Rouse, Krueger, and Markman (2004) present results from a randomized study of a well-defined program of computers use in US schools (grade 3 to 6): a popular instructional computer program, known as Fast ForWord, which is designed to improve language and reading skills. They assess the impact of the program using four different measures of language and reading ability. The causal effect is estimated using an OLS model where identification relies on randomization: i.e. in selected schools some students were randomly assigned Fast ForWord. Their estimates suggest that while use of the computer program may improve some aspects of students' language skills, it does not appear that these gains translate into a broader measure of language acquisition or into actual reading skills.

Banerjee, Cole, Duflo, and Linden (2007) look at the results of a randomized experiment conducted in schools in urban India (grade 3 and 4). A computer-assisted learning program was randomly assigned to some schools for up to two years. They find that the program was very effective, increasing math scores by 0.36 standard deviations the first year, and by 0.54 standard deviation the second year. However, they find that the effect of the program decays fast after the program ends, but this result is common to another treatment that provided teacher support rather than computer-assisted learning.

Subrahmanyam et al. (2001) survey the psychology literature. Several studies provide preliminary evidence that computer use is positively correlated with academic achievement. Few studies have examined the effect of children's time on computers on their social skills and friendships. The existing research suggests that frequent game players actually meet friends outside school more often than less frequent players and no differences have been found in the social interactions of computer game players vs. non-players. However most of these results apply mainly to teenagers.

2.4 Effect of TV use on Skills

To conclude our literature review we summarize the main findings on the effect of TV time on children's skills.

Gentzkow and Shapiro (2008) look at the effect of preschool television exposure on standardized test scores later in life. Using heterogeneity in the timing of television's introduction as a source of identification, they find that an additional year of preschool television exposure raises average test scores by about .02 standard deviations. These effects are largest for children from households where English is not the primary language, for children whose mothers have less than a high school education, and for non-white children.

Schmidt and Anderson (2007) provide an overview of the findings in the psychology literature. Exposure to educational programs, such as Sesame Street, has positive effect on children's vocabulary learning and this effect is long lasting. They do not find evidence that TV displaces intellectually valuable activities. In fact TV replaces activities similar to TV viewing such as radio listening, comic book reading and moviegoing.

3 The Production Function

In our data we observe the children at two points in time, when they are aged 4/5 (2004) and 6/7 (2006). Since it is unlikely that they made extensive use of a computer before age 4, let us start with a simple two period model $t = 1, 2$. Denote by C_t computer time at time t, by FI_t a vector of family inputs, by SI_t a vector of school inputs and by OM_t time spent using other media devices such as TV and video games. Let also μ denote children's unobserved time constant endowments (like innate abilities). Here μ is not 1 dimensional but rather a vector including a range of cognitive and non-cognitive innate abilities. Finally denote by T_{jt} the j^{th} test score measured at time t and by ϵ_t the measurement error in T_{jt}. As well as for μ, there is a vector of test scores T that can summarize the main cognitive and non-cognitive skills.

3.1 Period 1

The production function of each test score in period 1 can be written as:

$$T_{j1} = g_j(C_1, FI_1, SI_1, OM_1, \mu, \epsilon_1) \tag{1}$$

where we are assuming that any non-media input enters either FI_1 or SI_1. In this paper our parameter of interest is the effect of C_1 on T_{j1}, holding all other inputs constant. It is easy to see why the identification of this parameter is complicated by endogeneity problems. C_1 depends on the parental decision to own and make available a computer but also on the child decision to spend some time using it. Unobserved family, school and media inputs together with the child's innate abilities might be correlated with C_1 but also T_{j1}. Measurement error in C_1 can instead cause attenuation bias. In the data the parents were asked to report the time spent by their children using the computer. It is possible that some parents could only provide a rough guess. Therefore ϵ_1 can include measurement error in C_1. [2]

Todd and Wolpin (2003) discuss alternative estimation strategies under the assumption that the g function is linear, an assumption that we also make. Let X_1 denote observed family, school and other media inputs and let U_1 denote the unobserved ones.

$$T_{j1} = \alpha_{j1} + \beta_{j1} C_1 + X_1 \gamma_{j1} + v_{j1} \tag{2}$$

where $v_{j1} = U_1 \delta_{j1} + \mu \rho_{j1} + \epsilon_1$ ($\gamma_{j1}, \delta_{j1}, \rho_{j1}$ are vectors). The simplest way to estimate equation (2) is to use the OLS estimator and assume that we can control for the most important inputs influencing both C_1 and T_{j1} such that $E(v'_{j1} C_1) = 0$. The LSAC survey designers put a lot of care in collecting very detailed information regarding parental background, home and school care. In the results section we discuss what variables we can use to approximate the family, school and other media inputs. Yet even rich data can rarely allow to control for the innate abilities of the child μ. One possibility is to assume that the parental decision to own a computer is not a function of μ. That is parents own a computer mainly for their work, internet browsing or other personal uses so that the ownership decision does not depend on the children's characteristics. [3] If this is the case, and there are no other unobservable

[2] Test scores are the best available proxy of true skills, but they are still likely to measure these skills with errors. Thus skills's measurement error might also enter ϵ_1.

[3] In the data, parents were not asked whether they had a home computer but rather whether the child had access to one. Therefore parents had to take two decisions: whether to own a home computer and whether to make it available to the child. The latter could be correlated with μ. From the data, we only know whether the child had access to a computer at home. However, since in wave 1 (wave 2) 77% (88%) of the children had access to one, it is unlikely that many parents

entering both the parental decision and the production function, than computer ownership HC_1 can serve as an instrument for C_1 since $E(v'_{j1}HC_1) = 0$ but $E(HC'_1C_1) \neq 0$. [4] Using an IV is also the only way to solve the measurement error problem. Nevertheless, under heterogenous treatment effects the IV estimator will identify the Average Treatment on the Treated (ATT) and not the ATE. [5]

In period 1 it is also possible to test the robustness of OLS estimates by including a future measure of computer use C_2 in equation (2). Conditional on C_1, future computer use should not be correlated with T_{j1} unless μ or U_1 are correlated with C_2. [6]

3.2 Period 2

The production function in period 2 is:

$$T_{j2} = g_j(C_{2:1}, FI_{2:1}, SI_{2:1}, OM_{2:1}, \mu, \epsilon_2) \tag{3}$$

where the subscript $2:1$ indicates that we include both period 2 and 1 inputs. Every input of the production function at time 2 can have an effect on T_{j2} through its contemporaneous or lagged level. This is true also for computers where use in period 1 (age 4/5 in our data) might have permanent effects on the test scores besides the effect on C_2. If we only include C_2 its coefficient would pick up the effect of the whole computer history but we would not know when this input is most effective. According to Cunha et al. (2006) the timing of inputs matters because some skills can be shaped only when children are very young. Once again we assume that the production function is linear in its inputs:

$$T_{j2} = \alpha_2 + C_{2:1}\beta_{j2} + X_{2:1}\gamma_{j2} + v_{j2} \tag{4}$$

where $v_{j2} = U_{2:1}\delta_{j2} + \mu\rho_{j2} + \epsilon_2$. Therefore in equation (4) we are interested in estimating β_2 which is a 2×1 vector. The estimation of this equation is once again plagued by endogeneity problems potentially even more severe since now we are interested in the causal effect of the two endogenous variables C_1 and C_2. Besides OLS, Instrumental Variable estimation is still possible using HC_1 and HC_2 as instruments provided they are not multicollinear. However, consistency of the IV estimator now requires very strong restrictions on the time 2 parental decision. For $E(v'_{j2}HC_2) = 0$ to hold, the parental decision to own a computer at $t = 2$ must be uncorrelated with C_1 and T_1, since these are a function of μ, and T_1 is also a function of U_1. Todd and Wolpin (2003) discuss the estimation of the production function (4) using the Value Added model. The idea is to include a lagged test score T_{j1} on the right hand side. Intuitively, since the lagged test score is a function of μ, including it among the control variables one might reduce the omitted variable bias. However Todd and Wolpin (2003) also show that the Value Added model solves the endogeneity problem only if the impact of the ability endowment μ declines over time at a rate equal to the first order correlation across test scores. [7] Finally it is also possible to estimate the production function through the First Difference (or Fixed Effect) estimator. This

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had a computer but did not make it available. That reduces the choice space to a simple ownership decision.

[4] One argument against HC_1 satisfying the exclusion restriction is time displacement. Since the parents own a computer, presumably they spend some time using it. If parental computer time displaces time with the child, or time otherwise invested in producing T_{j1} inputs that we do not control for, then $E(v'_{j1}HC_1) \neq 0$. However, if parental computer time displaces "unproductive" time, for instance parental TV time, then the exclusion restriction holds.

[5] To see this note that under heterogenous treatment effects $\beta_{j1,i}$ the IV estimator would recover the LATE $= E[\beta_{j1,i}|C_1(HC_1 = 1) - C_1(HC_1 = 0) > 0]$ but since $C_1(HC_1 = 0) = 0$ by definition, the LATE = ATT $= E(\beta_{j1,i}|C_1 > 0)$.

[6] However, even if $E(C'_2\mu) = E(C'_2U_1) = 0$, C_2 might be correlated with ϵ_1. This would happen if C_2 is a function of previous period test scores T_1.

[7] This can be easily seen under linearity. Using equations (2) and (4), and letting $'$ and $''$ indicate the first and second element of the vectors β, γ, δ:

$$\begin{aligned} T_{j2} - \phi T_{j1} =& (\alpha_2 - \phi\alpha_1) + \beta''_2 C_2 + (\beta'_2 - \phi\beta_1)C_1 + X_2\gamma''_2 + X_1(\gamma'_2 - \phi\gamma_1) \\ &+ U_2\delta''_2 + U_1(\delta'_2 - \phi\delta_1) + (\rho_2 - \phi\rho_1)\mu + \epsilon_2 - \phi\epsilon_1 \end{aligned}$$

This also shows that U_2 and U_1 still enter the error term unless $\delta''_2 = (\delta'_2 - \phi\delta_1) = 0$. Moreover, C_2 will be correlated with ϵ_1 if previous test scores enter the parental or children choice functions.

estimator relies on other strong assumptions. The first two terms of v must be time constant, that is $(U_{2:1}\delta_{j2} + \mu\rho_{j2}) - (U_1\delta_{j1} + \mu\rho_{j1}) = 0$. Even if $C_{2:1}$ was orthogonal to $U_{2:1}$, the ability endowment must have a constant effect over time, $\rho_{j2} = \rho_{j1}$. In principle there is no reason why this should be the case and this equality holds for all the cognitive and non-cognitive abilities in the μ vector. Also, First Difference requires strict exogeneity. However this would be violated whenever C_2 is a function of T_1 either through the parental or children choice functions, since in that case $E(C_2'\epsilon_1) \neq 0$.

Later in the paper we provide estimates of the linear production functions in period 1 and 2. There are two main reasons why we estimate both functions rather than just the one in period 2. First, we are interested in the determinants of cognitive and non-cognitive skills because they, in turn, will act as determinants of educational choices and labor market outcomes. As much as both C_1 and C_2 might enter the period 2 production function, with C_1 still having a direct effect conditional on C_2, then we can also imagine a schooling or wage function where both T_1 and T_2 enter as inputs. If some learning processes, investments or choices are made at very young ages, T_1 might have a role even conditional on T_2. For this reason we are interested in the production functions of both T_1 and T_2. Second, in the data the vector of cognitive skill scores between period 1 and 2 is not the same, since some tests are age specific. Therefore the outputs of the production functions are not identical in the two periods. We refer to the data section for a more complete explanation of the cognitive skills measures.

4 Data

The data comes from the Growing Up in Australia, the Longitudinal Study of Australian Children (LSAC). This study aims to examine the impact of Australias unique social and cultural environment on the next generation. During 2004, over 10,000 children and their families were recruited to the study from a sample selected from the Health Insurance Commissions Medicare database. It is intended that these children and their families will be interviewed biannually until 2010, and possibly beyond. During 2004, the study recruited a sample of 5,107 infants (children born March 2003-February 2004) and 4,983 children aged 4-5 years (children born March 1999-February 2000) in a dual cohort cross-sequential design. Data for the first two waves of each cohort are now available. In what follows we focus on the older cohort, aged between 4 $\frac{1}{2}$ and 6 $\frac{1}{2}$ at the time of the two surveys. We then create our sample by selecting those children for whom data were collected at both waves.

4.1 Computer Access and Use

There are a number of variables that measure computer access/use by the child. In Wave 1 parents were asked whether the study child had access to a computer at home and if so, how many hours the child used the computer on a typical weekday and on a typical weekend day. Unfortunately in Wave 1 the number of hours were recorded in bands and not in continuous form. [8] Parents were also asked about the number of televisions at home and how many hours the child spent watching TV (still distinguishing between a weekday and weekend, and with hours coded in bands). If the child attended school, interviewers would interview the school's teacher, subject to parental authorization. Teachers were then asked whether the school was equipped with computers and how often the children used them. [9]

In Wave 2 parents were asked the same questions though this time computer and TV use were recorded as continuous variables. Moreover, in this second wave parents were also asked whether the children had access to a video game console such as Xbox, Playstation or Nintendo and if so, how many hours (weekday/weekend) they spent using it.

[8] The 5 bands were coded as follow: 1. Five or more hours; 2. From three to five hours; 3. From one to three hours; 4. Less than one hour; 5. No use.

[9] Provided the school was equipped with computers, frequency of use was coded as follows: 1. Two or more hours per day; 2. From one to two hours per day; 3. Less than one hour per day; 4. A few times a week; 5. A few times a month; 6. Less often; 7. Never.

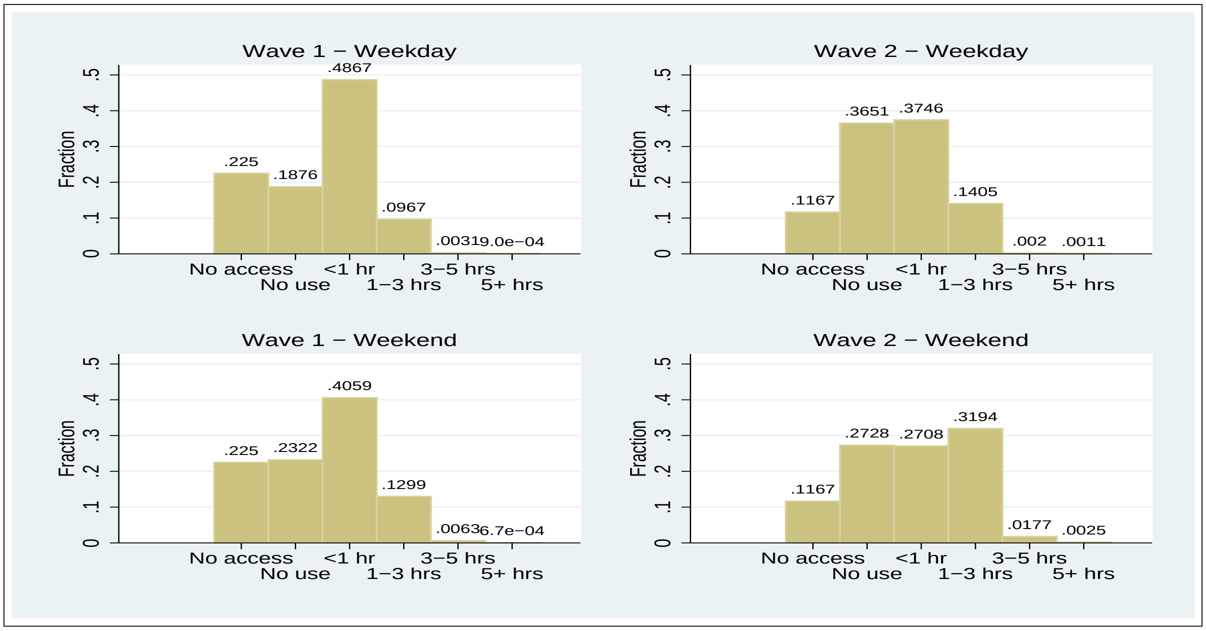

Figure 2: Home Computer Access and Use

Figure 2 shows computer access and use in waves 1 and 2. We distinguish between children who had no access to a computer (No access), those who had access but did not use it (No use) and those who had access and spent some time using it, where computer time is coded in 4 discrete hour bands (<1hr, 1-3hrs, 3-5hrs, 5+hrs). Children were more likely to have access to a computer in wave 2. By then only 11.67% of children could not access one. Perhaps parents decided to let the children use the computer as the children became older and started school or it could be simply the result of the upward trend in computer ownership that we have seen in figure 1. [10] On the other hand quite a large fraction of 6/7 year old children did not use a computer even if they had access to one. If we look at weekdays, the figure suggests that as they aged, children either did not use the computer at all or became heavier users of it. There is instead a clear increase in computer use during the weekend between the two waves.

Table 1: Media Access and Use

	Wave 1						Wave 2					
	All		Boys		Girls		All		Boys		Girls	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
PC Access	0.77	0.41	0.77	0.42	0.77	0.41	0.88	0.32	0.88	0.31	0.88	0.32
PC hours weekdays	1.78	2.28	1.84	2.51	1.72	2.01	1.67	2.67	1.76	2.68	1.57	2.65
PC hours weekends	0.70	0.85	0.72	0.89	0.68	0.80	1.21	1.51	1.31	1.65	1.10	1.33
Number of TV's	1.80	0.85	1.82	0.87	1.77	0.84	—	—	—	—	—	—
TV in bedroom	—	—	—	—	—	—	0.17	0.37	0.19	0.39	0.14	0.35
TV/DVD's hours weekdays	8.30	4.73	8.33	4.71	8.26	4.75	8.07	5.41	8.25	5.51	7.89	5.30
TV/DVD's hours weekends	3.89	2.06	3.90	2.09	3.88	2.02	4.81	2.89	4.93	2.97	4.69	2.79
video game console	—	—	—	—	—	—	0.53	0.49	0.68	0.46	0.39	0.48
VG hours weekdays	—	—	—	—	—	—	0.84	2.19	1.34	2.78	0.33	1.11
VG hours weekends	—	—	—	—	—	—	0.98	1.70	1.55	2.06	0.39	0.91
Observations	4464		2277		2187		4464		2277		2187	

In Table 1 we presents basic statistics on the use of computers, TV and video games. In wave 1

[10] Figure 1 shows that between 2004 and 2006 the fraction of Australian households owning a computer rose from 67% to 73%. That would account for more than a half the increase in computer access among the LSAC children. Nevertheless figure 1 is derived using a sample representative of all Australian households while the LSAC only includes those with young children.

information on media use was not as precise as in wave 2. Hours spent using a computer or watching TV were coded in bands, parents were not asked about video games and we know the total number of TV's in the house but not whether the child had one in his/her own bedroom. In order to construct the figures in table 1 (Wave 1) we recoded number of hours in continuous form. For both computer and TV hours, we used the median number of hours within each band from wave 2 and imputed that figure for wave 1 observations. [11] The average child was using the computer for a *total* of 1.78 hours during the week, and a *total* of 0.70 hours during the weekend. Boys spent more time than girls using it, but this difference is not very large. Importantly, there is evidence of variation over time. Not reported, the correlation between C_1 and C_2 is equal to 0.25. If C_1 and C_2 were to be multicollinear, estimation of equation (4) would be problematic resulting in large standard errors. In the appendix (table 13) we illustrate computer access/use variation over time, using the same coding as in figure 2. Children also spent 8 hours watching TV during the weekdays and almost 4 hours during the weekend. Once again boys stayed slightly longer than girls in front of a TV. In wave 2, when children were aged between 6 and 7 years old, almost everyone had access to a computer at home. Compared to wave 1, children used it less during the weekdays but more during the weekend, and a similar pattern exists also for TV use. Since in wave 2 children were aged 6 to 7 years old, and therefore all enrolled in school, it is possible that they had less home time during the week. Parents were also asked whether the child had his/her own TV in the bedroom. Almost one in five children had one. However no information was collected about the number of televisions at home. Finally in wave 2 more than half of the children had a video game console but boys spent remarkably more time than girls using it. Overall, at wave 2 an average (median) boy spent around 19 (17) hours using a combination of computer, TV and video games, while an average (median) girl spent 16 (14) hours.

Not reported in the table, the LSAC data also show that in wave 2 (wave 1) 81% (70%) of the schools had a computer in the classroom, though sample sizes are smaller, since not all children went to school (mainly in wave 1) or because the parents did not authorize the interviewer to go to the school.

Unfortunately the LSAC data does not contain information on what the children used the computer for. However, in 2006 the Australian Bureau of Statistics (ABS) has conducted a survey of 'Children's Participation in Cultural and Leisure Activities', which includes information details on children's use of computers and the internet for different age groups. In table 2 we report the main statistics. Children in the five to eight years group, our LSAC reference group, used the computer mainly to play games, followed by school or educational activities. The table also illustrates that as children age, less time is devoted to playing games while more and more time is spent in internet activities like browsing or emailing.

Table 2: Home Computer Usage, Activities

	5-8 yrs	9-11 yrs	12-14 yrs
Emailing or messaging	28.6	53.5	69.1
Other internet based activities	7.9	30.4	57.3
Playing games	87.7	80.7	69.9
School or educational	62.0	83.7	92.5
Other activities	3.3	2.9	3.8

Source: ABS. Study 4901.0 - Children's Participation in Cultural and Leisure Activities, Australia, Apr 2006.
Numbers in the table give the proportion of children carrying on that activity.

[11] Say that in wave 2 the median number of minutes for those children in the '1 to 3 hours' was 150, then we would impute 150 minutes also for those children that in wave 1 fall within this '1 to 3 hours' band.

4.2 Cognitive and Non-Cognitive Skills

The LSAC children were administered three cognitive skill tests depending on their age.

- **Who am I? Test** (Wave 1 only) The Who am I? is a direct child assessment measure that requires children to copy shapes (circle, triangle, cross, square, and diamond) and write numbers, letters, words and sentences. One item was added to the standard Who Am I? booklet for use in LSAC. It is used for the children at ages 4 to 5 years to assess the general cognitive abilities needed for beginning school.

- **Peabody Picture Vocabulary Test** (Waves 1 and 2) A short form of the Peabody Picture Vocabulary Test (PPVT - III), a test designed to measure a child's knowledge of the meaning of spoken words and his or her receptive vocabulary for Standard American English. This adaptation is based on work done in the United States for the Head Start Impact Study, with a number of changes for use in Australia. The Wave 1 and Wave 2 versions of the PPVT contain different, although overlapping, sets of items of appropriate difficulty for children aged 4-5 years and 6-7 years. A PPVT stimulus book with 40 plates of display pictures was used. The child is not required to define words but to show what they mean by pointing to (or saying the number of) a picture that best represents the meaning of the word.

- **Matrix Reasoning Test** (Wave 2 only) Children completed the Matrix Reasoning (MR) test from the Wechsler Intelligence Scale for Children, 4th edition (WISC-IV). This test of non-verbal intelligence presents the child with an incomplete set of pictures and requires them to select the picture that completes the set from 5 different options.

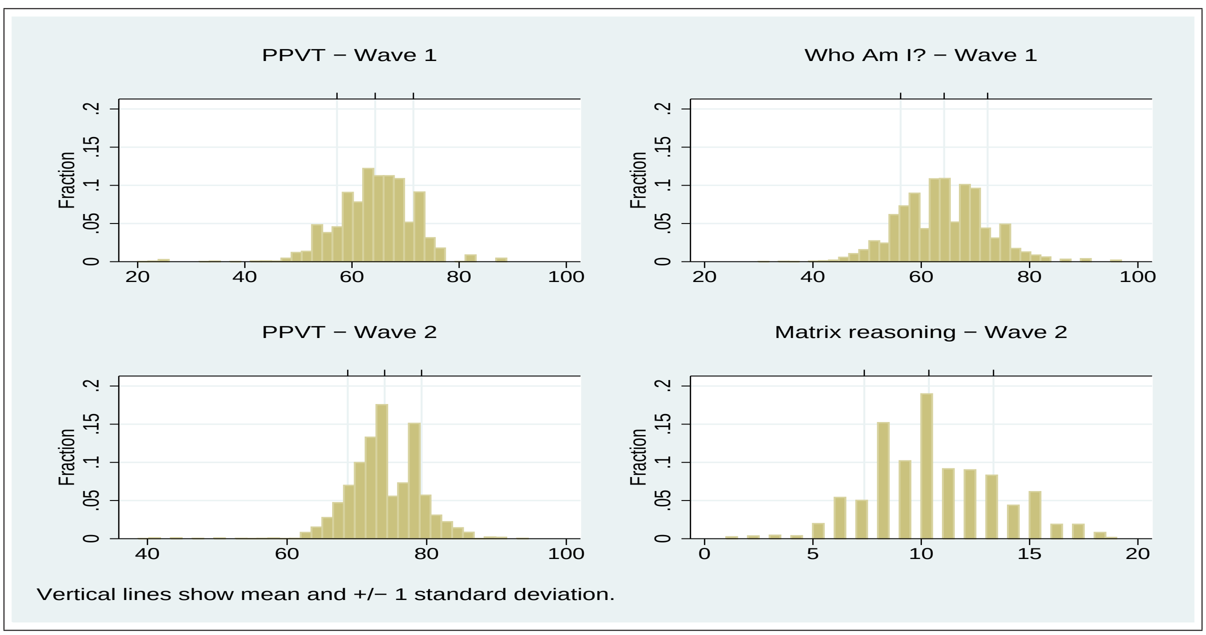

Figure 3: Cognitive Skills

Figure 3 shows the distribution of the cognitive test scores. Each distribution is quite symmetric. The matrix reasoning score has a different scale from the other tests. Later we standardize each test score to have mean zero and standard deviation 1.

In the LSAC, non-Cognitive skills are measured through both parental and teacher assessment. In the two waves parents and teachers were asked 25 questions about children's behavior. However, teachers' answers are available only if the child went to school and provided the parents authorized the interviewer to go to the school. Because of the larger sample size and in order to avoid sample selection (in school) problems, in the remaining of the paper we only use parental assessment. Most of the 25 questions did not change between the two waves and are described in the Appendix. From their answers LSAC data managers constructed five indicators of these skills.

- **SDQ Prosocial** Mean of 5 parent-rated items in the Prosocial subscale of the Strengths and Difficulties Questionnaire (SDQ), assessing the child's propensity to behave in a way that is considerate and helpful to others.
- **SDQ Hyperactivity** Mean of 5 parent-rated items in the Hyperactivity subscale of the SDQ, assessing child's fidgetiness, concentration span and impulsiveness.
- **SDQ Emotional symptoms** Mean of 5 parent-rated items in the Emotional Symptoms subscale of the SDQ, assessing a child's frequency of display of negative emotional states (e.g. nervousness, worry).
- **SDQ Peers** Mean of 5 parent-rated items in the Peer subscale of the SDQ, assessing problems in the child's ability to form positive relationships with other children.
- **SDQ Conduct** Mean of 5 parent-rated items in the Conduct subscale of the SDQ, assessing child's tendency to display problem behavior when interacting with others.

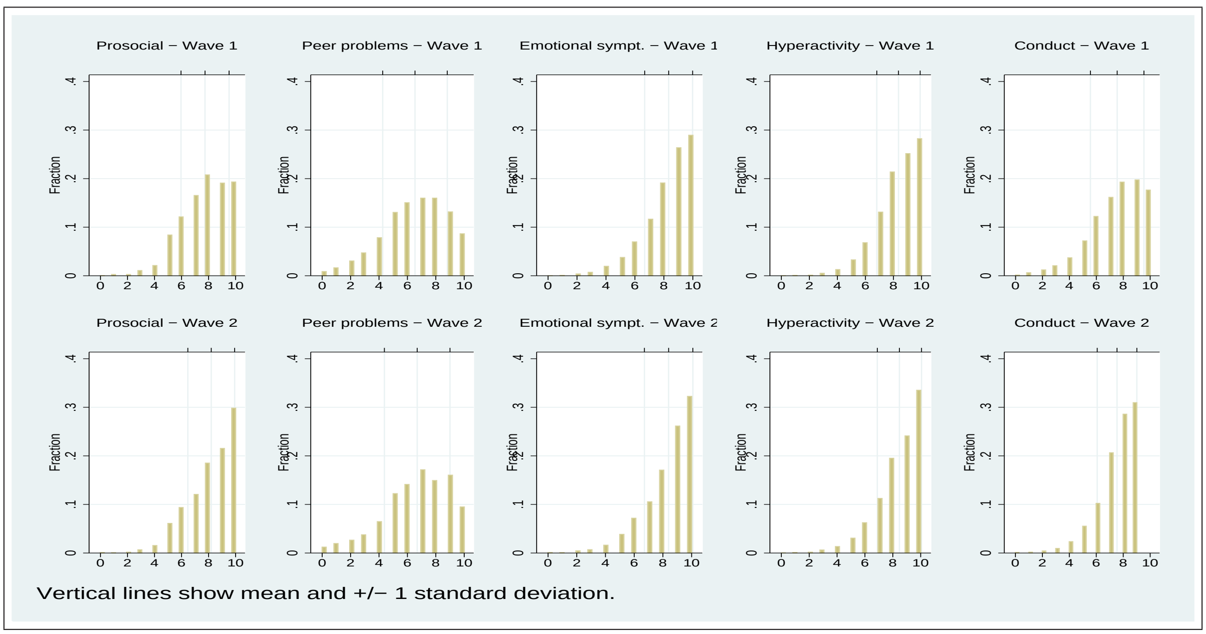

Figure 4: Non-Cognitive Skills

The non-cognitive scores are ordered such that a higher score corresponds to less behavioral problems, i.e. better non-cognitive skills. Figure 4 shows the distribution of the non-cognitive scores. These scores have right-skewed distributions (that is the majority of children do not have behavioral problems) and less variation than the cognitive scores. Non-cognitive scores are also standardized to have mean zero and standard deviation 1 before the estimation.

In table 3 we show the correlation matrix of the test scores for the two waves. The correlations between the cognitive and non-cognitive scores are positive and low as expected. The positive correlation is consistent with parental background driving skills, or with complementarities between these two kinds

Table 3: Skills Correlation Matrix

	Wave 1								Wave 2						
	ppvt	wai	soc	hypr	emot	peer	cond		ppvt	matrx	soc	hypr	emot	peer	cond
ppvt	1.00							ppvt	1.00						
wai	0.29	1.00						matrx	0.28	1.00					
soc	0.08	0.13	1.00					soc	0.06	0.03	1.00				
hypr	0.20	0.24	0.34	1.00				hypr	0.11	0.15	0.32	1.00			
emot	0.13	0.04	0.11	0.20	1.00			emot	0.07	0.04	0.10	0.23	1.00		
peer	0.16	0.11	0.26	0.24	0.38	1.00		peer	0.07	0.04	0.25	0.29	0.41	1.00	
cond	0.12	0.11	0.38	0.46	0.28	0.26	1.00	cond	0.10	0.09	0.38	0.48	0.33	0.33	1.00

of skills. The low correlation across scores suggests that they capture different dimensions of cognitive and non-cognitive skills. [12]

4.3 Other Variables of Interest

The LSAC is a very rich data set. Plenty of information was collected about the child, his/her household, home and school environments. In Table 4 we report basic statistics for a few variables. Children were on average 57 months old (almost 5 years old) in wave 1, and 83 months old (almost 7 years old) in wave 2. However there is a difference of 18 (22) months between the youngest and oldest child in wave 1 (wave 2), which can be quite important. These children had on average 1 $\frac{1}{2}$ siblings and in 95% of the case there were at most 3 siblings. The average mother was slightly younger than 30 years old at birth, and the average father slightly older than that. Most parents had some educational qualification beyond year 12 (high school). Father's income was substantially larger than mother's income, also due to a low fraction of mothers working full-time. The fraction of mothers working either full or part time rose between wave 1 and 2.

Table 4: Other Variables of Interest

	Wave 1		Wave 2	
	Mean	SD	Mean	SD
Child's Age (months)	57.40	2.62	83.66	2.97
Number of Siblings	1.47	1.02	1.58	1.03
Father Age (years)	37.50	5.86	39.48	5.97
Mother Age (years)	34.92	5.43	37.02	5.45
Father Higher Education	0.75	0.43	0.76	0.42
Mother Higher Education	0.64	0.47	0.68	0.46
Father Income (10 thous)	5.35	3.81	6.37	4.61
Mother Income (10 thous)	2.26	2.02	2.79	2.62
Mother Empl. Full-Time	0.20	0.40	0.25	0.43
Mother Empl. Part-Time	0.37	0.48	0.40	0.49

5 Results

In this section we provide estimates of the linear production functions in equations (2) and (4). Given the endogeneity problems discussed in section 3, and given that all estimators demand relatively strong assumptions, in what follows we report the parameters of interest of (2) and (4) using different estimators. All the test scores have been standardized to have mean zero and standard deviation 1. Computer time is measured as *total* weekly hours.

[12] To investigate this point further we also run a factor analysis using the principal-components factor method. At both waves we find three main factors. Upon rotation, the factor loadings suggest the following grouping: (1) PPVT and WAI scores; (2) SDQ Prosocial, Hyperactivity and Conduct scores; (3) SDQ Emotional symptoms and Peers scores.

5.1 Period 1 Estimation

In table 5 we present the estimated effects of computer use on cognitive and non-cognitive skills. The first column (OLSa) illustrates the estimated impact when controlling for some measures of family, school and other media inputs such as weekly hours in child care, indoor and outdoor activities involving a family member, hours spent watching TV. [13] Children using the computer more often score higher in the Peabody Picture Vocabulary and Who am I? tests. With regard to the non-cognitive scores, the SDQ Prosocial, Hyperactivity and Conduct coefficients are positive and significant at 1% level. Their positive coefficients indicate that children using a computer have better non-cognitive skills.

Table 5: Production Function - Period 1

	OLSa	OLSb	OLSc	IVa	$\bar{R}^2$/N	Future	$\bar{R}^2$/N
Peabody Pict. Vocabulary	0.024**	0.022**	0.022**	0.053**	0.21	-0.008	0.22
	(0.005)	(0.005)	(0.005)	(0.011)	3990	(0.011)	880
Who am I?	0.031**	0.029**	0.029**	0.045**	0.27	0.017	0.25
	(0.005)	(0.005)	(0.005)	(0.010)	4396	(0.009)	979
SDQ Prosocial	0.016**	0.015**	0.015**	0.030**	0.07	-0.023*	0.07
	(0.005)	(0.005)	(0.005)	(0.012)	4453	(0.011)	999
SDQ Hyperactivity	0.013**	0.010	0.010	0.019	0.13	-0.014	0.13
	(0.005)	(0.005)	(0.005)	(0.011)	4453	(0.010)	999
SDQ Emotional symptoms	0.006	-0.000	0.000	0.008	0.07	0.002	0.06
	(0.005)	(0.005)	(0.005)	(0.011)	4452	(0.011)	999
SDQ Peers	0.009	0.005	0.006	0.030**	0.10	0.004	0.07
	(0.005)	(0.005)	(0.005)	(0.011)	4453	(0.011)	999
SDQ Conduct	0.018**	0.013*	0.013*	0.038**	0.08	-0.021	0.08
	(0.005)	(0.005)	(0.005)	(0.011)	4453	(0.011)	999

Standard Errors in brackets. Stars indicate significance at 1% (**) and 5% (*) level.
OLSa: control for type of school, child home and outdoor activities with family members, child extra activities such as sport and music classes, computer in school, home TV time.
OLSb: like OLSa plus control for household demographics, parental education and financial situation.
OLSc: like OLSb minus parental income and other indicators of financial distress.
IV: like OLSb plus instrument computer time with computer access.
Future: like OLSb but explanatory variable is future computer time C_2 rather than C_1 and include only those children who did not have access to a computer in period 1.

In column OLSb we add a rich set of household characteristics such as parental education, income, number of siblings etc. None of the additional controls is a direct family (FI), school (SI) or other media (OM) input but we rather consider them as important determinants of these inputs. Since it is quite rare to observe all inputs, household characteristics are often used as proxies in similar studies. Some of these additional controls can also be viewed as proxies for the unobserved cognitive and non-cognitive endowment μ. Overall the coefficients are smaller but with no large change, though among the non-cognitive scores only the SDQ Prosocial coefficient is now significant at 1% level. This result is quite reassuring and it suggests that our set of inputs is quite comprehensive. Some researchers have criticized the use of household characteristics, and particularly of parental income, as a proxy of family or school inputs. They argue that an increase in the amount of an input holding income constant must imply a reduction in expenditures on other inputs. This could cause a misinterpretation of the coefficients. In column OLSc we then present the coefficients when excluding parental income and other indicators of financial distress from the set of control variables. The results are virtually identical to those in column OLSb. In the remaining of the paper we include parental income and other indicators of financial distress among the household characteristics.

To learn whether the effect is large or not we compare the computer coefficient in column OLSb to

[13] A full list of the control variables used in this and later tables is available in the Appendix. Note that in table 5 media activities are given by the number of hours watching TV/DVD's while for wave 2 we also include hours playing with videogame consoles.

those of TV/DVD and child care weekly hours (not reported in the table). [14] For the Peabody Picture Vocabulary, Who am I? and SDQ Prosocial scores, the TV/DVD coefficients are, in order of test score, -0.002, -0.008** and -0.008**, i.e. smaller and of opposite sign to the computer ones. The child care coefficients are -0.004, 0.008** and -0.001, again much smaller than the computer coefficients. Clearly endogeneity problems might bias these latter coefficients as much as the computer coefficient. However, unless the bias is large and possibly of different sign (i.e. computer coefficients are upward biased while TV/DVD and child care coefficients are downward biased) there is evidence that computer time is an important input in the production function.

Next we move to the IV estimator. Since we are not aware of any institutional change (laws or similar) that might affect C_t our approach is to use computer access at home (HC_1) to instrument C_1. In section 3.1 we discussed under what conditions this estimator is consistent. To satisfy the exclusion restriction we need computer access to be uncorrelated with unobserved inputs and the endowment. Given the large fraction of children with access to a home computer, we expect that, if anything, only a few parents owning a computer deny access to their children. Therefore it is unlikely that HC_1 is correlated with μ. In table 14 we then compare households with and without a computer over a number of observable characteristics. Households with a computer are on average older, better educated, richer and more likely to have the mother employed. Our assumption is that conditional on these and the other controls included in OLSb, households with and without a computer do not differ over any other unobserved input of the production function and that $HC_1 \perp \mu$. With regard to the rank condition, a first stage regression of C_1 on HC_1 and all other control variables used in OLSb show that HC_1 coefficient is positive and significant (see table 15, "Base" column, in the appendix). By definition the HC_1 coefficient is simply equal to $E(C_1|X_1, HC_1 = 1)$. Back to table 5, we see that under the IV estimator the return to computer use becomes larger for all cognitive and non-cognitive scores. This result is consistent with attenuation bias caused by measurement error in C_1 but not with omitted variable bias caused by unobserved innate abilities, which, at least in the case of cognitive scores, is expected to drive the coefficient upwards. It is also possible that the measurement error bias more than compensates for the omitted variable bias, or that the ATT identified by the IV estimator is larger than the ATE.

The fifth column ($\bar{R}^2$/N) reports the adjusted $\bar{R}^2$ for the richest OLS regression (OLSb) and the sample size (N). The $\bar{R}^2$ is larger for the cognitive scores production function.

Finally, we run a robustness test by estimating the effect of C_2 on T_1 (Future column). As discussed in section 3.1, conditional on C_1, future computer use C_2 should have no correlation with T_1 unless C_2 is a function of μ (skill endowments) and U_1 (unobserved inputs). If that was the case it is likely that $E(v'_{j1}C_1) \neq 0$. In order to properly control for current computer use we select only those children who did not have access to a computer in the first period. [15] In our sample 14.83 % of the children gained access to a computer between the two waves. Only in the case of the SDQ Prosocial score C_2 has a statistically significant effect. However, the C_2 coefficient is negative. If this is just an omitted variable bias, then the true β_{j1} is actually larger and not smaller than the OLS estimates.

To recap, both the OLS and IV estimator indicate that computer use in period 1 (age 4/5) has a positive statistically significant effect on the cognitive scores and on the SDQ Prosocial and Conduct scores, with the OLS coefficients being relatively large compared to those of other inputs. The OLS estimator passes the robustness check where we test for the effect of C_2 on T_{j1} for all scores but the SDQ Prosocial. However in this case, the negative coefficient suggests that the omitted variables might actually downward bias the estimates.

Table 6: Production Function - Period 2

		OLSa	OLSb	IV	$\bar{R}^2$/N	VA	$\bar{R}^2$/N
Peabody Pict. Vocabulary	C_2	0.005	0.004	-0.003	0.21	0.005	0.34
		(0.004)	(0.004)	(0.017)	4409	(0.004)	3960
	C_1	0.021**	0.020**	0.028*	—	0.011*	—
		(0.005)	(0.005)	(0.014)	—	(0.005)	—
Matrix Reasoning	C_2	0.008	0.008	0.016	0.09	0.006	0.16
		(0.004)	(0.004)	(0.018)	4402	(0.004)	4347
	C_1	0.030**	0.027**	0.058**	—	0.021**	—
		(0.005)	(0.005)	(0.015)	—	(0.005)	—
SDQ Prosocial	C_2	-0.005	-0.007	0.003	0.07	-0.004	0.29
		(0.004)	(0.004)	(0.018)	4342	(0.004)	4333
	C_1	0.007	0.007	0.015	—	-0.001	—
		(0.005)	(0.005)	(0.015)	—	(0.005)	—
SDQ Hyperactivity	C_2	-0.000	-0.002	0.005	0.14	0.001	0.41
		(0.004)	(0.004)	(0.018)	4341	(0.004)	4332
	C_1	-0.002	-0.001	0.007	—	-0.006	—
		(0.005)	(0.005)	(0.015)	—	(0.004)	—
SDQ Emotional symptoms	C_2	0.001	-0.001	0.025	0.08	0.001	0.25
		(0.004)	(0.004)	(0.018)	4341	(0.004)	4331
	C_1	0.008	0.003	-0.018	—	0.003	—
		(0.005)	(0.005)	(0.015)	—	(0.005)	—
SDQ Peers	C_2	-0.012**	-0.014**	-0.003	0.10	-0.009*	0.25
		(0.004)	(0.004)	(0.018)	4341	(0.004)	4332
	C_1	-0.004	-0.007	-0.014	—	-0.009	—
		(0.005)	(0.005)	(0.015)	—	(0.005)	—
SDQ Conduct	C_2	-0.002	-0.006	0.023	0.10	-0.003	0.31
		(0.004)	(0.004)	(0.018)	4341	(0.004)	4332
	C_1	0.009	0.008	0.023	—	0.001	—
		(0.005)	(0.005)	(0.015)	—	(0.005)	—

Standard Errors in brackets. Stars indicate significance at 1% (**) and 5% (*) level.
OLSa: control for type of school, child home and outdoor activities with family members, child extra activities such as sport and music classes, computer in school, home TV time.
OLSb: like OLSa plus control for household demographics, parental education and financial situation.
IV: like OLSb plus instrument computer time with computer access.
VA: like OLSb plus include lagged score on the right hand side.

5.2 Period 2 Estimation

In table 6 we show the parameter estimates for the period 2 production function (equation 4). For every test score function we report the C_2 (top) and C_1 (bottom) coefficients. The first three columns are obtained like in table 5 by controlling for family, school and other media inputs (OLSa), household characteristics (OLSb) and using computer ownership in both periods $HC_{2:1}$ to instrument $C_{2:1}$ (IV). The only difference is that for all OLS and IV estimators we now control for both periods characteristics ($X_{2:1}$) while in table 5 we controlled only for period 1 (X_1). Conditional on C_1, current computer use C_2 seems to have an effect only on the SDQ Peers score though the IV estimator is much smaller (in absolute value) and imprecise. The negative sign indicates that children spending more hours in front of the computer are more likely to have peer problems. However C_1 has a positive effect on both cognitive scores, with the IV estimator being larger than the OLS one. The fifth column ($\bar{R}^2$/N) report the adjusted $\bar{R}^2$ for the richest OLSc regression and the sample size (N). The Peabody Picture Vocabulary function is the one with the largest $\bar{R}^2$ while the Matrix Reasoning and other non-cognitive scores functions have a smaller $\bar{R}^2$.

[14]Child care hours are given by the average weekly hours in school, kindergarten, pre-school or day care.

[15]Alternatively, we could simply condition on C_1. However, C_1 might just be an imperfect proxy of current computer use.

We then estimate the production function using the Value Added estimator (VA column). In section 3.2 we discussed the conditions under which this estimator is consistent. The estimates are obtained after augmenting the right hand side of each production function with the period 1 test score. Most of the C_2 coefficients drop, including the SDQ Peers coefficient, though the latter is still negative and statistically significant. The C_1 coefficients drop too, but this is expected since we are including the lagged score on the right hand side (see section 3.2, footnote 7). As we would expect the $\bar{R}^2$ of the Value Added model is larger than the OLS estimator since the lagged score might be capturing the effect of unobserved innate abilities or past unobserved inputs. The sample size N is instead smaller since we only include those children for whom both periods scores are available.

We do not include the First Difference estimator instead mainly because the wave 1 computer hours were originally coded in bands. While it is already known that the First Difference estimator can exacerbate measurement error problems, in our case a ΔC variable created using our imputed continuous C_1 would generate even more measurement error. If instead we were to code both C_2 and C_1 in bands, we would loose all the children that did not change band between the two waves, roughly half of the sample.

To summarize, the results from period 2 suggest that computer use at young ages has a long lasting effect on cognitive skills, while current use has no strong effect. Per contra, C_2 has a negative effect on the SDQ Peers score, our indicator of the child's ability to form positive relationships with other children. That would be compatible with the hypothesis that children substitute time with other children with computer time. These results are consistent across the OLS, IV and Value Added estimators.

5.3 Non-linearities in the Production Function

So far we have maintained the assumption that the production function is linear in its inputs. In this section we test for non-linearities by introducing a quadratic term in C_1 and C_2. [16] Table 7 presents the result. For clarity, we only present the coefficients for the three cognitive skills and the SDQ Prosocial, SDQ Peers and SDQ Conduct non-cognitive skills, that is those skills for which C_t seems to matter. The table reports the OLSb estimator, column OLSb(T_t), the IV estimator, columns IV(T_t) and the value added estimator, column VA(T_2). In order to satisfy the order condition for the IV estimator we now need twice as many instruments as before, because of the quadratic term. To solve this problem we augment the first stage regression with the interactions between computer access on one side and number of siblings, number of older siblings, father's and mother's income on the other, while also including all these variables in their linear term. All the interactions have a positive and statistically significant coefficient in the first stage regression (see table 15 in the appendix, "Int" columns). Note also the large increase in the $\bar{R}^2$ once the interactions are included. [17] The OLS estimates show some evidence of a marginally decreasing return to C_1 for the cognitive scores, both in period 1 and 2, though the quadratic term coefficient is small. The mean (standard deviation) of C_1 is equal to 2.50 (2.87) weekly hours. Therefore, for all cognitive scores the return is still positive within 5 standard deviations from the mean. Some of the IV estimates are close to the OLS ones, but overall they are very imprecise. Turning to the SDQ Peers score, the Value Added estimates do not suggest concave or convex returns. Overall these results indicate that the production function is relatively linear in computer time.

5.4 Weekday vs Weekend

We now try to exploit the information in our data by separating C_t into weekday (C_t^{wd}) and weekend (C_t^{we}) computer hours: $C_t = C_t^{wd} + C_t^{we}$. The C_t coefficient is expected to lie in between the C_t^{wd} and

[16] We also include a quadratic term in other media time OM_t: TV and video games.

[17] Formally, we only need one interaction to satisfy the order condition. However, having more instruments could improve the precision of our estimates. In fact, we also tried to include all these interactions in section 5.1 and 5.2 but they made little difference.

C_t^{we} ones. [18] In table 8 we show the results. Once again we only present the coefficients for the three cognitive skills and the SDQ Prosocial, SDQ Peers and SDQ Conduct non-cognitive skills, and report the OLSb estimator, column OLSb(T_t), and the value added estimator, column VA(T_t). We omit instead the IV estimator since, like in the case of the non-linear production function, the IV estimates are very imprecise and therefore not informative.

Starting with the cognitive skills, we see that what is important is computer use during the weekend, with coefficients sensibly larger than those in tables 5 and 6. For the Matrix Reasoning test, C_2^{we} has now a statistically significant effect, even using the VA estimator, while in table 6 C_2 had a negligible effect. This is because the C_2 coefficient is a weighted sum of the C_2^{wd} and C_2^{we} ones. But why is it weekend computer time that matters? On the one hand since parents are more likely to be home (i.e. not working) during the weekend, they might be spending time with their children using educational software or other programs. On the other hand, it is possible that computer time during the weekday displaces other positive inputs of the cognitive production function, such as homework or other educational assignments, producing a zero sum effect, while during the weekend computer time displaces activities that are not cognitive skill enhancing, such that computer time has a net positive effect.

For the non-cognitive skills, whether it is the weekday or the weekend time that matters depends on the skill. In the case of the SDQ Prosocial function, it is weekday time that is important, though with an opposite sign between the two time periods. In the absence of information on computer activities and displaced activities, we do not have a clear intuition for this result. The SDQ Peers function shows instead a negative effect of C_2^{we}. If children using the computer during the weekend are less likely to form positive relationships with other children, it could be that computer time is displacing time playing and interacting with siblings or friends. It is also worth noting that the weekend coefficients have a larger standard error than the weekday ones.

5.5 Heterogeneity in the Production Function

In this section we investigate whether the production function parameters are heterogeneous. In particular we look at differences based on the children's sex and on their mothers's education and labor market status. Tables 9 and 10 illustrates the results for the two periods. For clarity we only report the OLSb estimator. Given the results in section 5.4, we also distinguish between C_t^{wd} and C_t^{we} and highlight the coefficients that were statistically significant in table 8.

For most scores, the impact of computer use is almost always larger for girls. There is some evidence that among teenagers, boys and girls use the computer differently, with boys spending more time playing games and girls using it more for emailing and chatting (see Subrahmanyam, Kraut, Greenfield, and Gross (2000)), though we do not know whether these differences in usage apply also to younger children. There is also evidence that boys and girls learn differently (see Gurian (2002)). However, a more complete investigation of these differences between boys and girls is beyond the scope of this paper.

Next, we divide our sample in three groups based on their mothers's education: below year 11, year 11 or 12 (completed high school), higher education. As we mentioned in the introduction, computer time might matter depending on the content and/or depending on the activities that are displaced by it. On the one hand, if it is content that matters, than children with better educated parents should have a higher return to computer time. This would be the case if better educated parents are more aware of which computer usages are educational or if they are more computer savvy themselves, and can teach their children how to use computers. On the other hand, if the effect comes mainly through the displaced activities, than children with low educated parents might have the highest return, since computer time might be more educational than time with parents. For instance, Bernal and Keane (2008) find that the effect of child care is positive mainly for children with low educated parents. The authors point at the displacement effect to explain this result. Tables 9 and 10 suggest that both channels might be in place. For most of the cognitive scores the effect of computer time is highest either for the low educated

[18] This is true if $Cov(C_t^{wd}, C_t^{ww}) > 0$, which is the case in our sample.

or the high educated parents groups.

Finally, we also test whether there is heterogeneity depending on the mother's working status. We distinguish between full-time, part-time and not working, the latter including mothers looking for a job, in maternity leave or out of the labor force. One way to explain a stronger return for weekend versus weekday time is to assume that parents can guide computer use better during the weekend, since they are more likely to be home and have time for the child. If this is true, than we would expect the difference between weekend and weekday use to be largest among children with working mothers. The last three columns of tables 9 and 10 indeed indicate that the difference between the weekend and weekday returns is larger for those children with mothers working full or part time. This result is also in line with the hypothesis that content matters.

5.6 Multimedia

Lastly, in this section we compare the return to computer, television and video games time. In Table 11 we present the result for the period 1 production function. The first columns correspond to the OLS return and is therefore identical to column OLSb in table 5. The second column (IV) differs from the one in table 5 because we now also instrument TV time with number of televisions in the house. That is we regress the scores on computer and TV time in the same regression and, for the IV estimates, instrument computer and TV time respectively with computer access and number of TV's in the house. The last two columns show the return to TV time.

Testing whether computer and TV time have a different return is interesting in light of our previous discussion. Both computers and TV are media devices, both will have an effect on children's skills depending on their content, on the activities they displace and on their intellectual stimulation. From table 11 it appears that computer and TV time have a very different effect. TV time has a statistically significant negative return an almost all scores, cognitive and non-cognitive. For both computer and TV time, the IV estimates are usually larger (in absolute value) than the OLS ones.

In table 12 we repeat the analysis for the period 2 production function. Now we also include, in the same regression, video game time, that is time spent playing games using consoles such as Xbox, Nintendo and Playstation. We only include period 2 media time and do not separate between current and lagged like we did in table 6. This is because we do not observe video games time in period 1 but we want to keep the estimates comparable across the three media devices. [19] The IV estimates are obtained instrumenting computer, TV and video games time with computer access, TV in child's bedroom (yes/no) and video game console access. It is unfortunate that in period 2 we do not observe number of televisions in the house. It is quite unlikely that the presence of a TV in the child's bedroom, as much as access to video game console, are uncorrelated with the child's characteristics. Nevertheless we still include the IV estimates for completeness. We also show the Value Added estimates obtained by including the lagged score on the right hand side. Television has still a negative effect for most of the scores, no matter which estimator is used, though the Value Added estimates are generally smaller. The effect of spending time playing with video games is also mostly negative even though only for the Peabody Picture Vocabulary score this effect is statistically significant.

6 Conclusions

The objective of this paper was to investigate the effect of using a home computer for children's cognitive and non-cognitive development. Data show that in OECD countries 70% or more of the households have a computer at home. Our Australian data also show that in families with young children this percentage can go up to almost 90% and that children do make use of computers even at very young ages. However not much is know about the effect of computers. Computers are a relatively new input in the children

[19] We do not include lagged computer, TV and video game time but we do include current and lagged measures for all other control variables.

production function having entered the average household mainly in the last fifteen years. Previous research in economics has focused on the effect of computer on the adults' wage production function (with controversial findings), on high school graduation (positive effect) or on the effect of computer use in school, the latter often specific to a particular computer-assisted learning program (mixed findings). Psychologists instead have already completed some studies on the effect of home computer usage but data is mainly available for teenagers and some of these studies do not deal with the endogeneity of computer time.

In our work we use data from an Australian cohort born in 2000, with information collected in 2004 and 2006. The advantage of using this sample is twofold. These children are very young and data is recent. The latter is an important characteristic since computers, software, internet availability and parental computer's skills all have changed sensibly in the last two decades. We are not aware of any similar study.

For cognitive skills, our results indicate that computer time has a positive effect. The effect is long-lasting with early computer use showing an impact on test scores even two years later. This positive effect originates mainly from computer time during the weekend, is larger for girls, for children with low or highly educated parents and for children with working parents. The effect is large relatively to those of other inputs, such as child care, and is not shared by other media devices, such as television and video games which instead show a negative effect. This pattern of results suggests that the impact of computer time might be coming from different channels. First, by what computers are used for, i.e. content, since it is positive for children with highly educated parents and not for televisions and video games use. Second, because of the activities displaced by computer time, since the largest effect is found for children with low educated parents. Third, and again given the negative effect of television, because a computer is a very interactive device and therefore intellectually stimulating.

For the non-cognitive skills the evidence is more mixed, with the sign of the effect depending on the score and the age of the children. For the SDQ Prosocial score, which assess the child's propensity to behave in a way that is considerate and helpful to others, we find a positive effect for children aged between 4 and 5 years. This effect is larger for girls, and for children with highly educated and working parents. However two years later the effect turns negative. For the SDQ Peers score, which assesses the child's ability to form positive relationships with other children, we find a negative effect in period 2, mainly due to computer time during the weekend. It is harder to interpret the mixed effects on non-cognitive skills. A negative weekend effect is however consistent with the displacement of time spent in company of other children or adults. Nevertheless, a more exhaustive investigation of the mechanisms behind the computer effect would demand information on actual computer activities, which are not available in our data.

We test the robustness of our results by comparing OLS, IV and Value Added estimators. Generally, the IV estimates are larger and the Value Added estimates lower than the OLS ones. However the pattern of result is quite consistent. We also test for omitted variable bias by testing whether future computer time has any effect on current score. Only in the case of the SDQ Prosocial score we find evidence of a correlation with unobserved characteristics, but if anything, the bias might be attenuating the effect rather then reinforcing it.

Table 7: Production Function - non-linearities

Cognitive Skills		OLSb(T_1)	IV (T_1)	OLSb(T_2)	IV(T_2)	VA(T_2)
Peabody Pict. Vocabulary						
	C_2	—	—	0.002	-0.053	0.003
		—	—	(0.006)	(0.054)	(0.006)
	C_2^2	—	—	0.000	0.006	0.000
		—	—	(0.000)	(0.006)	(0.000)
	C_1	0.042**	0.041	0.024**	0.003	0.009
		(0.007)	(0.055)	(0.007)	(0.055)	(0.007)
	C_1^2	-0.001**	0.002	-0.000	0.004	0.000
		(0.000)	(0.008)	(0.000)	(0.008)	(0.000)
Who am I?						
	C_2	—	—	—	—	—
		—	—	—	—	—
	C_2^2	—	—	—	—	—
		—	—	—	—	—
	C_1	0.048**	0.049	—	—	—
		(0.007)	(0.051)	—	—	—
	C_1^2	-0.001**	-0.001	—	—	—
		(0.000)	(0.008)	—	—	—
Matrix Reasoning						
	C_2	—	—	0.013	0.055	0.011
		—	—	(0.007)	(0.052)	(0.007)
	C_2^2	—	—	-0.000	-0.004	-0.000
		—	—	(0.000)	(0.006)	(0.000)
	C_1	—	—	0.048**	0.064	0.037**
		—	—	(0.008)	(0.053)	(0.008)
	C_1^2	—	—	-0.001**	-0.001	-0.001**
		—	—	(0.000)	(0.008)	(0.000)

Non-Cognitive Skills		OLSb(T_1)	IV (T_1)	OLSb(T_2)	IV(T_2)	VA(T_2)
SDQ Prosocial	C_2	—	—	-0.004	-0.049	-0.000
		—	—	(0.007)	(0.069)	(0.006)
	C_2^2	—	—	-0.000	0.005	-0.000
		—	—	(0.000)	(0.007)	(0.000)
	C_1	0.021**	0.051	0.007	-0.032	-0.004
		(0.007)	(0.059)	(0.008)	(0.076)	(0.007)
	C_1^2	-0.000	-0.003	-0.000	0.008	0.000
		(0.000)	(0.009)	(0.000)	(0.012)	(0.000)
SDQ Peers	C_2	—	—	-0.011	0.002	-0.008
		—	—	(0.007)	(0.075)	(0.006)
	C_2^2	—	—	-0.000	0.000	-0.000
		—	—	(0.000)	(0.008)	(0.000)
	C_1	0.006	-0.001	-0.008	0.056	-0.010
		(0.007)	(0.062)	(0.008)	(0.082)	(0.007)
	C_1^2	-0.000	0.005	0.000	-0.011	0.000
		(0.000)	(0.009)	(0.000)	(0.013)	(0.000)
SDQ Conduct	C_2	—	—	-0.008	0.022	-0.002
		—	—	(0.007)	(0.056)	(0.006)
	C_2^2	—	—	0.000	-0.001	-0.000
		—	—	(0.000)	(0.006)	(0.000)
	C_1	0.019**	-0.008	0.014	0.001	0.003
		(0.007)	(0.068)	(0.008)	(0.062)	(0.007)
	C_1^2	-0.000	0.007	-0.000	0.004	-0.000
		(0.000)	(0.010)	(0.000)	(0.010)	(0.000)

Standard Errors in brackets. Stars indicate significance at 1% (**) and 5% (*) level.

Table 8: Production Function - Weekday vs Weekend

Cognitive Skills					Non-Cognitive Skills				
		OLSb(T_1)	OLSb(T_2)	VA(T_2)			OLSb(T_1)	OLSb(T_2)	VA(T_2)
Peabody Pict. Vocabulary									
	C_2^{wd}	—	0.004	0.005	SDQ Prosocial	C_2^{wd}	—	-0.013*	-0.012*
		—	(0.006)	(0.005)			—	(0.006)	(0.006)
	C_2^{we}	—	0.007	0.006		C_2^{we}	—	0.010	0.017
		—	(0.011)	(0.010)			—	(0.011)	(0.010)
	C_1^{wd}	0.009	0.021**	0.012		C_1^{wd}	0.020*	0.009	-0.000
		(0.008)	(0.008)	(0.007)			(0.008)	(0.008)	(0.007)
	C_1^{we}	0.073**	0.014	0.006		C_1^{we}	0.001	-0.004	-0.009
		(0.022)	(0.022)	(0.021)			(0.023)	(0.024)	(0.021)
Who am I?									
	C_2^{wd}	—	—	—	SDQ Peers	C_2^{wd}	—	-0.006	-0.002
		—	—	—			—	(0.006)	(0.006)
	C_2^{we}	—	—	—		C_2^{we}	—	-0.031**	-0.024*
		—	—	—			—	(0.011)	(0.010)
	C_1^{wd}	0.015*	—	—		C_1^{wd}	0.003	-0.006	-0.007
		(0.007)	—	—			(0.008)	(0.008)	(0.008)
	C_1^{we}	0.078**	—	—		C_1^{we}	0.016	-0.006	-0.016
		(0.020)	—	—			(0.022)	(0.023)	(0.021)
Matrix Reasoning									
	C_2^{wd}	—	-0.005	-0.006	SDQ Conduct	C_2^{wd}	—	-0.011	-0.005
		—	(0.006)	(0.006)			—	(0.006)	(0.005)
	C_2^{we}	—	0.037**	0.034**		C_2^{we}	—	0.006	0.005
		—	(0.011)	(0.011)			—	(0.011)	(0.010)
	C_1^{wd}	—	0.016	0.014		C_1^{wd}	0.011	0.001	-0.004
		—	(0.008)	(0.008)			(0.008)	(0.008)	(0.007)
	C_1^{we}	—	0.063**	0.044		C_1^{we}	0.020	0.029	0.017
		—	(0.023)	(0.023)			(0.022)	(0.023)	(0.020)

Standard Errors in brackets. Stars indicate significance at 1% (**) and 5% (*) level.

Table 9: Heterogeneity in the Production Function - Period 1

		Boys	Girls	M low Edu	M mid Edu	M high Edu	M work FT	M work PT	M not Wkg
Peabody Pict. Vocabulary									
	C_1^{wd}	0.013	-0.007	0.015	-0.001	0.017	-0.013	0.011	-0.002
		(0.010)	(0.014)	(0.017)	(0.019)	(0.011)	(0.016)	(0.011)	(0.016)
	C_1^{we}	0.049	0.109**	0.098	0.044	0.072**	0.120**	0.081*	0.059
		(0.029)	(0.036)	(0.072)	(0.054)	(0.028)	(0.042)	(0.035)	(0.042)
	N	2031	1959	542	856	2591	793	1502	1691
Who am I?									
	C_1^{wd}	0.008	0.021	-0.006	0.020	0.024*	0.008	0.014	0.028*
		(0.009)	(0.013)	(0.013)	(0.018)	(0.011)	(0.016)	(0.011)	(0.014)
	C_1^{we}	0.077**	0.094**	0.151**	0.028	0.066*	0.072	0.103**	0.036
		(0.026)	(0.032)	(0.056)	(0.051)	(0.026)	(0.044)	(0.032)	(0.036)
	N	2236	2160	599	938	2857	887	1650	1853
SDQ Prosocial									
	C_1^{wd}	0.018	0.031*	0.009	0.040	0.022	0.043*	0.030*	-0.007
		(0.011)	(0.014)	(0.016)	(0.022)	(0.012)	(0.017)	(0.013)	(0.016)
	C_1^{we}	-0.011	0.005	0.054	-0.019	-0.010	-0.013	-0.056	0.070
		(0.031)	(0.035)	(0.067)	(0.059)	(0.028)	(0.046)	(0.037)	(0.041)
	N	2268	2185	609	953	2889	898	1674	1875

Standard Errors in brackets. Stars indicate significance at 1% (**) and 5% (*) level.

Table 10: Heterogeneity in the Production Function - Period 2

		Boys	Girls	M low Edu	M mid Edu	M high Edu	M work FT	M work PT	M not Wkg
Peabody Pict. Vocabulary									
	C_2^{wd}	0.003	0.013	-0.004	-0.001	0.007	0.003	0.006	0.007
		(0.009)	(0.009)	(0.017)	(0.020)	(0.007)	(0.016)	(0.008)	(0.012)
	C_2^{we}	0.008	-0.008	-0.060	0.009	0.005	0.011	-0.002	0.003
		(0.014)	(0.018)	(0.037)	(0.028)	(0.013)	(0.025)	(0.017)	(0.020)
	C_1^{wd}	0.021*	0.027	0.030	0.031	0.023*	0.018	0.010	0.052*
		(0.010)	(0.014)	(0.017)	(0.023)	(0.011)	(0.014)	(0.012)	(0.022)
	C_1^{we}	0.002	0.036	0.162*	-0.052	0.003	0.006	0.052	-0.038
		(0.029)	(0.036)	(0.079)	(0.061)	(0.027)	(0.045)	(0.035)	(0.046)
	N	2248	2161	551	843	3013	1122	1805	1481
Matrix Reasoning									
	C_2^{wd}	-0.004	-0.008	-0.021	-0.008	0.004	-0.020	-0.012	0.021
		(0.009)	(0.009)	(0.016)	(0.022)	(0.008)	(0.017)	(0.009)	(0.012)
	C_2^{we}	0.047**	0.026	-0.001	0.043	0.032*	0.059*	0.046*	-0.004
		(0.015)	(0.019)	(0.035)	(0.031)	(0.014)	(0.026)	(0.019)	(0.021)
	C_1^{wd}	0.010	0.030*	-0.004	0.033	0.031**	0.006	0.007	0.045*
		(0.010)	(0.015)	(0.016)	(0.025)	(0.012)	(0.015)	(0.013)	(0.023)
	C_1^{we}	0.039	0.109**	0.190*	-0.069	0.054	0.091	0.107**	0.025
		(0.032)	(0.038)	(0.076)	(0.067)	(0.030)	(0.048)	(0.038)	(0.048)
	N	2244	2158	552	843	3005	1117	1804	1480
SDQ Peers									
	C_2^{wd}	-0.001	-0.012	-0.025	-0.072**	0.005	-0.012	-0.000	-0.012
		(0.010)	(0.009)	(0.019)	(0.022)	(0.008)	(0.018)	(0.009)	(0.013)
	C_2^{we}	-0.039*	-0.028	0.024	0.010	-0.042**	-0.012	-0.028	-0.052*
		(0.016)	(0.018)	(0.041)	(0.031)	(0.014)	(0.027)	(0.018)	(0.022)
	C_1^{wd}	-0.012	0.010	-0.022	-0.014	0.002	0.018	-0.014	-0.014
		(0.011)	(0.014)	(0.019)	(0.026)	(0.012)	(0.015)	(0.012)	(0.024)
	C_1^{we}	-0.010	-0.016	0.169	0.047	-0.045	-0.065	0.030	0.008
		(0.033)	(0.036)	(0.089)	(0.072)	(0.028)	(0.048)	(0.036)	(0.052)
	N	2220	2121	544	829	2966	1104	1794	1443

Standard Errors in brackets. Stars indicate significance at 1% (**) and 5% (*) level.

Table 11: Multimedia Production Function - Period 1

	PC		TV	
	OLSb	IV	OLSb	IV
Peabody Pict. Vocabulary	0.022**	0.053**	-0.002	-0.056**
	(0.005)	(0.012)	(0.003)	(0.018)
Who am I?	0.029**	0.044**	-0.008**	-0.045**
	(0.005)	(0.011)	(0.002)	(0.016)
SDQ Prosocial	0.015**	0.030**	-0.008**	0.006
	(0.005)	(0.012)	(0.003)	(0.017)
SDQ Hyperactivity	0.010	0.018	-0.014**	-0.032
	(0.005)	(0.011)	(0.002)	(0.017)
SDQ Emotional symptoms	-0.000	0.007	-0.012**	-0.032
	(0.005)	(0.011)	(0.003)	(0.017)
SDQ Peers	0.005	0.030**	-0.011**	-0.004
	(0.005)	(0.011)	(0.003)	(0.017)
SDQ Conduct	0.013*	0.038**	-0.016**	-0.015
	(0.005)	(0.011)	(0.003)	(0.017)

Standard Errors in brackets. Stars indicate significance at 1% (**) and 5% (*) level.
IV: instrument computer time with computer access and TV time with number of televisions in the house.

Table 12: Multimedia Production Function - Period 2

	PC			TV			VG		
	OLSb	IV	VA	OLSb	IV	VA	OLSb	IV	VA
Peabody Pict. Vocabulary	0.008	0.015	0.007	0.001	-0.064	0.002	-0.018**	-0.016	-0.012**
	(0.004)	(0.016)	(0.004)	(0.002)	(0.050)	(0.002)	(0.004)	(0.021)	(0.004)
Matrix Reasoning	0.013**	0.049**	0.009*	-0.005*	-0.090	-0.002	-0.004	0.036	-0.004
	(0.004)	(0.018)	(0.004)	(0.002)	(0.056)	(0.002)	(0.005)	(0.024)	(0.005)
SDQ Prosocial	-0.006	0.008	-0.004	-0.002	0.023	0.001	0.005	0.008	0.006
	(0.004)	(0.015)	(0.004)	(0.002)	(0.050)	(0.002)	(0.005)	(0.020)	(0.004)
SDQ Hyperactivity	-0.003	0.013	0.000	-0.006**	-0.112	-0.001	-0.000	0.036	-0.002
	(0.004)	(0.018)	(0.003)	(0.002)	(0.058)	(0.002)	(0.005)	(0.024)	(0.004)
SDQ Emotional symptoms	-0.000	0.020	0.001	-0.005*	-0.098	-0.005*	-0.001	0.035	-0.001
	(0.004)	(0.018)	(0.004)	(0.002)	(0.058)	(0.002)	(0.005)	(0.024)	(0.004)
SDQ Peers	-0.015**	-0.004	-0.011**	-0.002	-0.110	-0.000	-0.006	0.061*	-0.008
	(0.004)	(0.019)	(0.004)	(0.002)	(0.060)	(0.002)	(0.005)	(0.025)	(0.004)
SDQ Conduct	-0.005	0.040*	-0.002	-0.008**	-0.130*	-0.004*	-0.002	0.035	0.002
	(0.004)	(0.020)	(0.004)	(0.002)	(0.063)	(0.002)	(0.005)	(0.026)	(0.004)

Standard Errors in brackets. Stars indicate significance at 1% (**) and 5% (*) level.
IV: instrument computer time with computer access, TV time with television in child's bedroom (binary) and video games time with video game console access.

Appendix

Variation in Computer Access and Use Over Time

Table 13: Home Computer Access and Use Over Time

	Wave 2						
	No access	No use	<1 hr	1-3 hrs	3-5 hrs	5+ hrs	Total
Wave 1			Weekday				
No access	7.65	7.54	5.18	2.09	0.02	0.02	22.50
No use	1.68	9.15	5.95	1.93	0.02	0.02	18.76
<1 hr	1.97	17.52	22.14	6.89	0.07	0.07	48.67
1-3 hrs	0.38	2.27	3.97	2.98	0.07	0.00	9.67
3-5 hrs	0.00	0.09	0.13	0.09	0.00	0.00	0.31
5+ hrs	0.00	0.00	0.02	0.07	0.00	0.00	0.09
Total	11.69	36.57	37.40	14.05	0.18	0.11	100.00
			Weekend				
No access	7.65	6.30	3.97	4.38	0.18	0.02	22.50
No use	1.79	8.73	6.62	5.81	0.25	0.02	23.22
¡1 hr	1.79	9.94	13.73	14.63	0.43	0.07	40.59
1-3 hrs	0.43	2.22	2.63	6.82	0.81	0.09	12.99
3-5 hrs	0.00	0.11	0.09	0.31	0.09	0.02	0.63
5+ hrs	0.00	0.02	0.02	0.02	0.00	0.00	0.07
Total	11.67	27.33	27.06	31.97	1.75	0.22	100.00

Numbers in table are percentages.

Information used to construct Non-Cognitive skills

Each skill score is equal to the mean of 5 parent-rated items. Some item scores are re-ordered for consistency. Whenever a question changed between the two waves, this is indicated by specifying the wave to which the question refers.

- **SDQ Prosocial**
    1. Considerate of other peoples feelings;
    2. Shares readily with other children (treats, toys, pencils, etc);
    3. Helpful if someone is hurt, upset or feeling ill;
    4. Kind to younger children;
    5. Often volunteers to help others (parents, teachers, other children);
- **SDQ Hyperactivity**
    1. Restless, overactive, cannot stay still for long;
    2. Constantly fidgeting or squirming;
    3. Easily distracted, concentration wanders;
    4. Thinks things out before acting;
    5. Good attention span, sees chores or homework through to the end;
- **SDQ Emotional symptoms**
    1. Often complains of headaches, stomach aches or sickness;
    2. Many worries, often seems worried;
    3. Often unhappy, depressed or tearful;
    4. Nervous or clingy in new situations, easily loses confidence;
    5. Many fears, easily scared;
- **SDQ Peers**
    1. Rather solitary, tends to play alone;
    2. Has at least one good friend;
    3. Generally liked by other children;
    4. Picked on or bullied by other children;
    5. Gets on better with adults than with other children;
- **SDQ Conduct**
    1. Often loses temper;
    2. Generally well behaved, usually does what adults request;
    3. Often fights with other children or bullies them;
    4. Often argumentative with adults (wave 1); Often lies or cheats (wave 2);
    5. Can be spiteful to others (wave 1); Steals from home, school or elsewhere (wave 2);

Control variables used in tables 5 and 6.

We use the abbreviations 's.c.' (study child), and 'no.' (number).

- **OLSa**:

  FI : family member home activities with the s.c. in the last week (read to s.c. from a book; told s.c. a story not from a book; drawn pictures or did other art or craft activities with s.c.; played music, sang songs, danced or did other musical activities with s.c.; played with toys or games indoors, like board or card games with child; involved child in everyday activities at home, such as cooking or caring for pets; played a game outdoors or exercised together like walking, swimming, cycling); family member outdoor activities with the s.c. in the last month (gone to a movie; gone to a playground or a swimming pool; gone to sporting event in which child was not a player; gone to a live performance for children, like a concert or play; attended a school, cultural or community event; attended a religious service, church, temple, synagogue or mosque; visited a library); s.c. regularly spoken to in a language other than English by parents, babysitters or at child care/pre-school/ school; s.c. regularly attended special or extra cost activities that are not part of his/her normal child care, pre-school or school activities in the last 6 months? (swimming; gymnastics/kindergym; team sport; musical instruments or singing; ballet or other dance; children's religious group; other);

  SI : type of school attended by the s.c. (adjusted by age); grade or year level in school; does child go to a school, kindergarten, pre-school or a day care centre? (wave 1); no. of hours on average per week s.c. goes to (school/ kindergarten/ pre-school/ day care) (wave 1); no. of different schools attended since beginning fulltime schooling (wave 2); computer in school (room has use of a computer; how often do the children have access to the computer).

  OM : TV hours; video game hours (wave 2).

- **OLSb**: OLSa controls +age (child); state of residence; age (parents); s.c. relationship to parents (biological or not); no. of people in home; grandmother in home; grandfather in home; no. of siblings; no. of young siblings; no. of same age siblings; no. of brothers; no. of sisters; no. of younger brother; no. of younger sisters; s.c. has a step- or half-sibling in home; s.c. has an adopted sibling in home; s.c. has a foster sibling in home; parental education; parental work status; financial problems in the last 12 months (could not pay gas, electricity or telephone bills on time; could not pay the mortgage or rent payments on time; went without meals; were unable to heat or cool your home; pawned or sold something because needed cash; sought assistance from a welfare or community organization); parents' annual income; language parents first spoke as a child; country grandparents were born.

Instrumental Variable

Table 14: Comparing households with and without a home computer

	Wave 1	Wave 2
Child's Age (months)	-0.024	0.003
Number of Siblings	0.028	-0.091
Father Age (years)	0.713**	0.782*
Mother Age (years)	1.819**	1.803**
Father Higher Education	0.085**	0.100**
Mother Higher Education	0.141**	0.139**
Father Income (10 thous)	1.120**	1.492**
Mother Income (10 thous)	0.211**	0.460**
Mother Employed Full-Time	0.020	0.083**
Mother Employed Part-Time	0.118**	0.121**

Numbers in table are $E(X_t|HC_t = 1) - E(X_t|HC_t = 0)$.
Stars indicate significance at 1% (**) and 5% (*) level.
$HC_1 = 1$: household with home computer.
$HC_1 = 0$: household without home computer.

Table 15: First Stage regression

	C_1		C_2	
	Base	Int.	Base	Int.
Computer Access (CA)	3.240**	0.830**	3.474**	0.799**
	(0.099)	(0.052)	(0.176)	(0.076)
Number of Siblings	-0.041	-0.537**	-0.029	-0.682**
	(0.134)	(0.064)	(0.311)	(0.129)
Number of Younger Siblings	-0.191	-0.123	-0.212	-0.073
	(0.199)	(0.095)	(0.356)	(0.149)
Father's Income	0.008	-0.070**	0.024	-0.133**
	(0.013)	(0.008)	(0.017)	(0.008)
Mother's Income	-0.011	-0.322**	-0.013	-0.250**
	(0.025)	(0.015)	(0.029)	(0.014)
CA*Number of Siblings Int	—	0.240**	—	0.225**
	(—)	(0.005)	(—)	(0.005)
CA*Number of Younger Siblings Int	—	0.164**	—	0.113**
	(—)	(0.011)	(—)	(0.009)
CA*Father's Income Int	—	0.026**	—	0.041**
	(—)	(0.002)	(—)	(0.001)
CA*Mother's Income Int	—	0.116**	—	0.074**
	(—)	(0.003)	(—)	(0.003)
$\bar{R}^2$	0.21	0.82	0.10	0.84

Standard Errors in brackets. Star at 1% (**) and 5% (*) level.
Base: include Computer Access plus all the controls in OLSb (see Appendix).
Int.: like Base plus interaction of Computer Access with number of siblings, number of younger siblings, father's and mother's income.

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