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Abstract

Recent empirical research in family economics has shown the importance of parental investments on child's human capital development, but it is still not clear whether parents respond to changes across time in their child's skills and health. Using the Longitudinal Study of Australian Children, we measure parental investments by considering the time parents spend with their child doing formative activities. By adopting a child fixed-effect instrumental variable estimation to address endogeneity issues, we find that parents reinforce for differences in their child's socio-emotional skills, compensate for changes in her physical health, and are neutral to variation in her cognitive skills.

Keywords: Time-use, family investment, quality time, skills, child development.

JEL codes: J13, D13, C23, C26

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1 Introduction

The behavioural response of parental investments to child endowments has attracted a lot of researchers' attention, but there is not yet consensus on whether parents compensate or reinforce for differences in child's human capital across time (Currie and Almond, 2011; Almond and Mazumder, 2013). Most of the empirical literature has focused either on the reaction of parental investments to siblings' and twins' differences in endowments at birth or in early childhood[1] or to exogenous health shocks caused, for example, by flu epidemics.[2]

On the contrary, in our paper we focus on the response of parental investments to their child's human capital by observing their time investment in two points in time, when children are 6-7 and 8-9 years old. Furthermore, while previous studies on parental investments have generally ignored the multi-dimensionality of the child's human capital (two exceptions are given by Attanasio et al., 2015a and Yi et al., 2015), we consider the response of parental time investments to three different dimensions of child's human capital, namely health, cognitive and socio-emotional skills.

Using time-use diaries collected in the Longitudinal Study of Australian Children (LSAC), we measure parental investments by considering the time parents spend in formative activities with their child.[3] Unlike proxies of time investment, such as parents' employment status and number of working hours, our measure of time investment reflects the "quality" time that parents spend with children. Furthermore, it differs from most of the other measures of investment considered in the empirical literature by being more reactive and therefore allowing to better capture the potential response of parents to changes in their child's health, cognitive and socio-emotional skills. Empirical evidence shows indeed that other types of investment, such as mothers' worked hours and the Home Observation Measurement of the Environment (HOME) index, have much less variation across time then the parental time investment.[4]

[1] See Behrman et al. (1994); Royer (2009); Rosenzweig and Zhang (2009); Datar et al. (2010); Currie and Almond (2011); Hsin (2012); Aizer and Cunha (2012); Del Bono et al. (2012); Rosales-Rueda (2014); Yi et al. (2015) Restrepo (2016).

[2] See Kelly (2011), Adhvaryu and Nyshadham (2012); Parman (2012); Venkataramani (2012).

[3] Similar definitions of parental investments based on time-use diaries have been used by Stafford and Yeung (2004), Hsin (2007), Price (2008), Hsin (2009), Carneiro and Rodrigues (2009), Del Boca et al. (2014), Fiorini and Keane (2014) and Del Boca et al. (2016).

[4] By using the LSAC and measuring parental investments when the child is 6-7 and 8-9 years old, we find that 60% or more of the variance in the HOME index and the mother's worked hours is explained by a

We estimate a parental investment model by regressing the time parents spend with their child at 6-7 (8-9) years old on the child's cognitive and socio-emotional skills and health measured when the child is 4-5 (6-7) years old and controlling for other types of investments in children, in particular for childcare and household income. To take into account unobserved heterogeneity and, more specifically, unobserved family, school and environment characteristics that are time invariant in the child's life period between 6 and 9 years, we use a panel data approach and express our model in first-differences, therefore controlling for child (individual) fixed-effects. We estimate this first-differences model by using an instrumental variable approach to correct for potential biases caused by (i) the presence of time varying unobservables that may affect both the child's human capital and parental investments and (ii) the reverse causality issue, i.e. the fact that the time parents spend with their child may improve their child's level of human capital. Specifically, we instrument the first differences in child's skills and health with past measures of skills and health.

This child fixed-effect instrumental variable estimation has similarities with the estimator proposed by Arellano and Bond (1991), but the endogeneity issue in our investment model is not caused by the inclusion of a lagged dependent variable but by the inclusion of endogenous measures of child's human capital. Our instrumental variable approach is also similar to the one proposed by Rosenzweig and Wolpin (1995) to identify the effect of maternal prenatal investments on the child's human capital at birth. The main difference is that while Rosenzweig and Wolpin (1995) use variation within households across siblings, we use variation within child across time.

Economic models capturing how parental investments react to changes in the child's human capital are complex and depend on the interactions of several factors: (i) the cost of investments and the parental resources; (ii) the productivity of the investment or the parental belief on this productivity;[5] (iii) parental preferences for child quality, (iv) allocation of resources among several children.[6] Without imposing restrictive assumptions on all the above

fixed-effect component that does not vary across time, while this percentage reduce to 43.6% for the parental time investment.

[5]Recent papers have emphasized that if the parental beliefs about the investment productivity are biased, then the parental investment decisions depend on these beliefs rather than the actual investment productivity (Cunha et al., 2013; Cunha, 2014; Attanasio, 2015; Boneva and Rauh, 2016)

[6]See e.g. the economic models considered by Behrman et al., 1982; Becker and Tomes, 1986; Caucutt and Lochner, 2012; Del Boca et al., 2014.

factors, the sign of the effect of child's human capital on parental investments is ambiguous and ultimately a question to be investigated empirically.

Using the LSAC to estimate the parental time investment model and adopting a child fixed-effect instrumental variable estimation, we find that parental investments react positively to an improvement in their children's socio-emotional skills, negatively to an increase in their physical health and are neutral to changes in their children's cognitive skills. By running some sensitivity checks, we also provide some insights on the role of some of the above factors in explaining parental investment decisions.

The reinforcing investment response to child's socio-emotional skills that we find may be unexpected, but it could be explained by the lack of parental time resources and by the psychic costs of interacting with a child with behaviourial issues (above factor (i)). When exploring these mechanisms, we find that the effect of a change in socio-emotional skills is not statistically different from zero for parents with less stringent time constraints (households with non-working mothers) and this effect shrinks for children with no tantrums. However the differences in the effect are not statistically significant.

We also investigate whether the zero effect of the child cognitive ability on parental time investment may be explained by parental beliefs on productivity (above factor (ii)). If parents believe that the time a child spends with a teacher has larger cognitive skills' returns than the time they spend with the child, then this would explain the zero effect of the child's cognitive skills on time investment. To check this, we estimate the effect of child's cognitive skills on the time a child spends in lessons and we find indeed that parents compensate for cognitive skills when considering such investment.

Parental preferences for child quality (above factor (iii)) is another potential factor explaining investment strategies and these preferences are likely to differ by socio-economic background and child's gender. However we do not find strong evidence for any statistically significant difference, except for the fact that, while parents compensate for change in their daughters' physical health, they are neutral to changes in their sons' physical health.

Our model does not take explicitly into account the potential presence of siblings and does not tell us anything about the allocation of resources across children (above factor (iv)). Nevertheless, because we control for the child fixed-effect we are actually accounting for parental investments in the child's siblings if these are invariant in the 2-year period we consider. Furthermore, to account for the presence of siblings that may attenuate the parental investment response, we compare the parental investment between one-child households and households with more children. The empirical evidence suggests that parents with only one child tend to compensate more for all three measures of their child's human capital, but not significantly differently from parents with more than one child.

Because we are concerned about potential differences between subjective measures of human capital reported by parents and the corresponding objective measures, we also assess if objective and subjective measures have a different effect on parental time investment.[7] Results are encouraging as they suggest that the potential bias caused by the parental miss-perception of changes in child's socio-emotional skills is negligible.

Finally, we test the validity of our instrumental variable estimation by (i) using a larger number of instrumental variables and testing the validity of the over-identifying restrictions; (ii) checking whether our estimation results change when controlling for health shocks of family members, relatives and close friends, which could be correlated with unobserved characteristics affecting both past child's human capital (our instruments) and the current parental time investments; (iii) assessing the effect of measurement errors on child's human capital and on time investments.

The remainder of the paper is organized as follows. Section 2 discusses the related literature and our contribution. Section 3 presents the conceptual framework and estimation strategy of the parental time investment model, while Section 4 compares our estimation with other potential alternatives. We describe the sample and variables in Section 5, while we report our main results in Section 6. We also present empirical evidence on the validity of our child fixed-effect instrumental variable estimation in Section 7, and we report the results on the heterogeneity of the parental investment response in Section 8. Finally, Section 9 provides some conclusions.

[7] See Dizon-Ross (2013) and Kinsler and Pavan (2016) for evidence on inaccurate parental beliefs about children's cognitive skills.

2 Previous literature

There is a widening literature on the response of parental investments to child endowment at birth. Almond and Mazumder (2013) present a useful review of this literature and discuss the related econometric challenges. In this section, we summarise such literature and extend it by considering the response of parental investments to child's human capital, measured during childhood rather than at birth. Furthermore, we review those studies that have assessed the effect of parental time investment on children outcomes by using time diaries. Finally, we report the main differences and the contribution of our paper with respect to previous literature.

2.1 Investment response to endowments at birth: Sibling fixed-effect estimation

Most of the empirical evidence on the response of parental investments has been provided using samples of siblings (or twins) and evaluating how sibling differences in parental investments respond to sibling differences in birth weight, but no consensus has been reached yet on whether investments strategies are compensating, reinforcing or neutral. Royer (2009) finds no effect of differences in birth weight between twins on mothers' breastfeeding decision and on neonatal medical care, while Datar et al. (2010) show that postnatal investments (e.g. breastfeeding initiation and immunization) are higher for the sibling with a higher birth weight. Hsin (2012) looks at sibling differences in the mother's time investments[8] and provides evidence of a compensating behaviour for highly-educated mothers and a reinforcing one (but not statistically significant) for lowly-educated mothers. Restrepo (2016) considers sibling differences in parental investment measured by the Home Observation for Measurement of the Environment (HOME) score and finds a reinforcing investment strategy for lowly-educated parents and a compensating one for highly-educated parents. Finally, Currie and Almond (2011) suggest that there is generally no difference in parental investments between twins except for a higher concern about kindergarten readiness for the twin with lower birth weight.

[8]Time investment is measured in two ways: considering the total time mothers spend with their child and the time that they spend in human capital enhancing activities.

2.2 Investment response to endowments at birth: Rosenzweig and Wolpin (1988 and 1995) method

Evaluating the effect of endowments at birth on postnatal parental investments by considering a family fixed-effect estimation may lead to biased results because of non-random differences in birth endowments between siblings. Differences in endowments at birth can depend on unobserved differences in inputs during pregnancy that may be correlated with differences in postnatal parental investments. An approach to correct for the endogeneity of the endowment at birth, which was first proposed by Rosenzweig and Wolpin (1988), is to estimate the effect of the child's endowment at birth net of the effect of prenatal investments and of sibling-invariant endowment and family characteristics, which they call *child-specific endowment* (see also Pitt et al., 1990; Rosenzweig and Wolpin, 1995; Aizer and Cunha, 2012; Del Bono et al., 2012). This approach consists of two stages: in the first stage a human capital production model is estimated by regressing the child's endowment at birth on prenatal parental investments using family fixed-effects and instrumental variables to correct for the endogeneity, while in the second stage a family fixed-effect estimation is applied to the regression of postnatal parental investment on child-specific endowment (which is estimated using the child idiosyncratic error in the first stage) and a set of control variables.

Using a similar approach, Rosenzweig and Wolpin (1988) show that children with higher health endowment are more likely to be breastfed than their less healthy siblings, providing evidence of parents' reinforcing investments. Del Bono et al. (2012) find that breastfeeding initiation and duration are negatively related to child-specific endowment, therefore suggesting that mothers compensate for differences between siblings. On the contrary, Aizer and Cunha (2012), who extend the approach of Rosenzweig and Wolpin (1988) to correct for measurement errors in the estimated child-specific endowment and in the mother's investment,[9] find that the mother's investment tends to reinforce for differences in endowments between siblings.

[9] By exploiting the availability of multiple measures of birth endowments (birth weight, gestation, head circumference and body length) they use a factor analysis to extract the latent common endowment. Similarly they measure mother's investment by extracting the common latent factor of 7 different measures of mother's parenting behaviour.

2.3 Investment response to endowments at birth: Indirect evidence

Some studies provide 'indirect evidence' (as called by Almond and Mazumder, 2013) of parental investments responsiveness by comparing estimations of the impact of the child's endowments on outcomes measured later in life using and without using family (sibling) fixed-effect. Loughran et al. (2008) explain the logic behind this indirect evidence and suggest that a larger (smaller) effect of the child's endowments when using family fixed-effect would be indicative of a reinforcing (compensating) behaviour. By looking at birth weight effect on the child's cognitive outcomes later in life, they find that parents compensate for low birth weight, at least when looking at long-term outcomes. Using this type of evidence Almond et al. (2009) find that parental investments are reinforcing when evaluating the damage caused by exposure to Chernobyl radioactive fallout on educational achievements.

2.4 Investment response to endowments during childhood: Extensions of the sibling fixed-effect estimation

The assumptions imposed by the estimation procedure proposed by Rosenzweig and Wolpin (1988) and Rosenzweig and Wolpin (1995) are generally less credible when the focus is on the response of parental investments to the child's endowment measured during childhood or later in life rather than at birth. Alternative methods have been used to correct for the endogeneity of the child's endowments measured later in life. They usually consider family fixed-effects and correct for the residual endogeneity of the child's endowment by either controlling thoroughly for prenatal investments and the child's characteristics (e.g. Rosales-Rueda, 2014) or by exploiting exogenous variation in the child's endowment using instrumental variables (e.g. Frijters et al., 2013) or natural exogenous shocks (e.g. Yi et al., 2015).

Rosales-Rueda (2014) analyses how parental investment, proxied by the HOME score, responds to health conditions during childhood. She corrects for the bias caused by the potential endogeneity of health conditions by using family fixed-effect and controlling for the child's characteristics and prenatal parental investments. Her results show a reinforcing parental behaviour in the case of mental illness, but no statistically significant response of parental investment to physical health conditions is observed. Frijters et al. (2013) examine the responsiveness of the HOME score to cognitive test scores and correct for the potential endogeneity bias by adopting a family fixed-effect estimation and instrumenting the cognitive test scores using the child handedness. They find that parents reinforce for differences in cognitive skills between siblings. Yi et al. (2015) study the effect of twin differences in health shocks in early childhood on twin differences in parental investments in China. Health shocks are measured by serious diseases (e.g. diarrhoea, calcium deficiency, asthma and fracture) when children are between 0 and 3 years old. They find a compensating behaviour when parental investments are measured in terms of medical expenditure and a reinforcing one in the case of educational expenditure.

2.5 Investment response to endowments during childhood: Dynamic latent factor models

While the papers mentioned above have as a main goal to explore the response of parental investments to the child's human capital, in this section we review some recent papers that estimate the production process of the child's skills and health focusing on the role of different inputs. These studies do not provide a direct estimation of the response of parental inputs to the child's human capital, but they account for the endogeneity of parental inputs caused by the *feedback effect* from parental inputs to the child's human capital. In doing this, they provide some suggestive evidence on whether parental investments are compensating or reinforcing for the child's low human capital. These studies usually adopt dynamic latent factor models to estimate the production process of the child's human capital at different stages of the child's life as a function of past skills, parental human capital and a variety of inputs including parents' investments (see Cunha and Heckman, 2008).

These models make use of multiple measures available for each of the inputs and skills, which are assumed to be related to the true common latent skills and inputs, in order to recover the relationships between the unobserved latent skills and inputs. Furthermore, they take into account the endogeneity of inputs and, in particular, of parental investments by using instrumental variables.

Cunha and Heckman (2008) find no significant changes in their results when correcting for the endogeneity of the parental inputs, while Cunha et al. (2010), considering a non-linear (rather than linear) dynamic factor model, find evidence of a compensating investment strategy. Attanasio et al. (2015a) and Attanasio et al. (2015b) also use dynamic factor models and correct for the bias caused by the endogeneity of the parental investments by adopting a control function approach (i.e. using the estimated residuals of the investments models as additional explanatory variables in the production models). Both these papers show that parents adopt a compensating behaviour as indicated by the underestimation bias of the effect of investments on the child's human capital when ignoring the endogeneity of parents' investments. In particular, Attanasio et al. (2015a) find that parents compensate for low socio-emotional skills by increasing the time spent with their child, whereas they compensate for low cognitive skills by increasing their material investments.

2.6 The effect of parental time investment on the child's human capital

There exists only a handful of studies using time-use diaries to assess the relationship between parental investments and child endowments and they generally evaluate the effect of time investments on child's endowments, rather than the response of parental investment (except for Hsin, 2012). Overall they show a positive effect of parental time investments on child development.

Using information from time-use diaries of children available in the Child Development Supplement of the Panel Study of Income Dynamics, Hsin (2007) finds that maternal time spent with the child during pre-school years has a positive effect on child's cognitive skills measured five years later, but only for verbally-skilled mothers. Additional evidence of the effect of time investment using the same survey is provided by Del Boca et al. (2014), who show that maternal time increases the child's cognitive skills, although the effect attenuates as the child gets older (see also Carneiro and Rodrigues, 2009).

Del Boca et al. (2016) use again the Child Development Supplement of the Panel Study of Income Dynamics and focus on the effect of time children spend in formative activities on their own and together with their mothers on their cognitive abilities during adolescence. They find that the mother's time investment matters less than children's own time investment. Fiorini and Keane (2014) use time-use diaries collected in the Longitudinal Study of

Australian Children and show that time parents spend on educational activities with their children has a positive effect on their children's cognitive skills.

Evidence of the importance of parental time investments for child development is also found using surveys that approximate time investments with information on the type and frequency of parental activities (e.g. Del Bono et al., 2014 and Attanasio et al., 2015a) and the length of maternity leave (e.g. Carneiro et al., 2015). Del Bono et al. (2014) find that mothers' time spent in educational and recreational activities have positive effects on cognitive and socio-emotional skills of their children. This effect decreases with the child's age for cognitive skills but not for socio-emotional skills. Results from a study by Attanasio et al. (2015a) show time investments being more relevant for socio-emotional skills, while material investment being more important for cognitive skills. Finally, Carneiro et al. (2015) use exogenous variation in the time mothers spend with their newborns caused by a maternity leave reform and find that mothers' time investments in infants have a significant effect even on long-term outcomes, such as wages and high school completion.

2.7 Differences between our paper and previous studies

The review of previous studies has highlighted a large variability in the parental investment strategy when considering different types of parental investments that range from breast-feeding practices and immunization to expenditure in the child's education and health. Nevertheless, when focusing on parental time investments, there seems to be a consensus that time investments benefit child development and that parents compensate for the child's low endowments by increasing their time with the child, at least in the case of highly-educated mothers (see Hsin, 2012; Del Boca et al., 2014; Attanasio et al., 2015a).

Our paper adds to this literature by providing for the first time a comprehensive analysis of the response of time investments to changes in the child's cognitive, socio-emotional and physical health. Furthermore, while most of the previous literature has focused exclusively on parents with at least two children to use sibling fixed-effect estimation, we consider parents with any number of children so that we are able to evaluate the investment strategy even in absence of other children in the family. Contrary to those papers that use sibling fixed-effect estimation, we control for unobserved inputs and family characteristics by using a panel data approach and adopting a child fixed-effect estimation. Therefore, we are able to account for all unobserved inputs that do not vary across time, or at least in the period considered when children are 6-7 and 8-9 years old.

3 The parental time investment model

3.1 The conceptual framework

In the economics literature it is usually assumed that parents maximize a utility function that depends on parental consumption and on their child's human capital or future wages, income or wealth (see Behrman et al., 1982; Becker and Tomes, 1986). We assume that parents make decisions in each child's life stage of development, denoted with the subscript t, and that there are T sequential stages between birth and adulthood, $t = 1, ..., T$ (see Del Boca et al., 2016). Following this approach, we assume that parents care about their consumption and their child's human capital and we consider the following parents' utility function in stage t:

$$U_t(C_{i,t}, \boldsymbol{\theta}_{i,t}, \boldsymbol{\theta}_i^P), \tag{1}$$

where i denotes the child (household), $C_{i,t}$ is the parental consumption, $\boldsymbol{\theta}_{i,t} = [\theta_{it}^H, \theta_{it}^C, \theta_{it}^S]$ is a column vector with three measures of the child's human capital which are health, cognitive and socio-emotional skills respectively, and $\boldsymbol{\theta}_i^P$ is a vector of measures of parents' human capital that do not change across stages. We allow parental human capital, $\boldsymbol{\theta}_i^P$, to enter the utility function because of potential heterogeneity of investment preferences across parents with different endowments and because parents' utility can depend on the difference between their own human capital and the one of their child. For example, parents might have an aversion to intergenerational inequity and prefer to transmit to their child a level of human capital similar to theirs.

In each stage t of the development process, parents are assumed to maximize the expected discounted sum of their utilities under the child's human capital production and budget constraints. Following Cunha et al. (2010) and Almlund et al. (2011) we allow the human capital to be multi-dimensional and we assume the production of human capital of type k for child i in stage t to be given by:

$$\theta_{it}^k = h_{k,t}(\boldsymbol{\theta}_{i,t-1}, I_{i,t}^{Time}, I_{i,t}^{Care}, I_{i,t}^{School}, \boldsymbol{\theta}_i^P, \upsilon_i^k, \eta_{i,t}^k), \tag{2}$$

where θ_{it}^{k} is the child's human capital of type k; with $k = H, C$ and S denoting health, cognitive and socio-emotional skills respectively. $I_{i,t}^{Time}$ is the parental time investment, $I_{i,t}^{Care}$ represents childcare inputs while $I_{i,t}^{School}$ indicates school inputs.[10] υ_i^k represents time invariant child's and parents' characteristics that might affect the production of human capital of type k, and $\eta_{i,t}^{k}$ is an idiosyncratic shock in stage t, which can affect the production of human capital of type k. We assume that what parents observe when deciding the investment level in t is $\boldsymbol{\theta}_{i,t-1}$, $\boldsymbol{\theta}_i^P$, υ_i^k and the idiosyncratic shocks, $\eta_{i,t}^{k}$ for $k = H, C$ and S.

Finally, we assume that the budget constraint at stage t is given by

$$Y_{i,t} = C_{i,t} + p_t^T I_{i,t}^{Time} + p_t^{Care} I_{i,t}^{Care} + p_t^{School} I_{i,t}^{School}, \tag{3}$$

where $Y_{i,t}$ is parental income; p_t^{Time}, p_t^{Care} and p_t^{School} are the prices of parental time, childcare and school inputs.

We do not impose any additional assumption on the utility function (1) and on the human capital production model (2) except regularity conditions (in particular, the strict concavity and twice continuously differentiability) to ensure the problem is well-behaved and to allow for the existence of a unique solution for the parental time investment model.

We approximate the optimal parental time investment in child i in stage t by the following function:

$$I_{i,t}^{Time} = f_t(\boldsymbol{\theta}_{i,t-1}, \boldsymbol{\theta}_i^P, Y_{i,t}, I_{i,t}^{Care}, I_{i,t}^{School}, p_t^{Time}, p_t^{Care}, p_t^{School}, \upsilon_i^H, \upsilon_i^C, \upsilon_i^S, \mu_i^I, \eta_{i,t}^H, \eta_{i,t}^C, \eta_{i,t}^S, u_{i,t}), \tag{4}$$

where $u_{i,t}$ is an idiosyncratic shock affecting parental time investment, which we assume to be independent of the production shocks $\eta_{i,t}^H$, $\eta_{i,t}^C$ and $\eta_{i,t}^S$, whereas μ_i^I represents time invariant child's and parents' characteristics that might affect the time investment beside υ_i^H, υ_i^C and υ_i^S.

3.2 Econometric Strategy

In this section we present the econometric approach we apply to identify the effect of the child's human capital on parental time investment.

[10] For the time being we consider these investments as univariate variables, but in the empirical application we will measure school and childcare inputs using multiple variables.

In the empirical analysis, we follow a cohort of Australian children from stage 0 (age 4-5, year 2004). We observe parental time investment in stages 1 (age 6-7, year 2006) and 2 (age 8-9, year 2008) and their human capital in stages 0 and 1. By assuming that the investment model (4) is linear and additive in its inputs and it does not change between stages 1 and 2, we can rewrite it as

$$I_{i,t}^{Time} = \alpha_0 + \alpha_1 d_{i,t} + \boldsymbol{\theta}'_{i,t-1}\boldsymbol{\gamma} + \boldsymbol{\theta}_i^P \boldsymbol{\beta} + Y_{i,t}\rho + I_{i,t}^{Care}\lambda + I_{i,t}^{School}\psi + \mu_i + \epsilon_{i,t}, \tag{5}$$

where $t = 1$ or 2, $d_{i,t}$ is a dummy taking value 1 for stage 2 (year 2008) and 0 for stage 1 (year 2006) capturing any potential macro change between stages (e.g. changes in the price of investments p_t^{Time}, p_t^{Care} and p_t^{School} between 2006 and 2008), $\boldsymbol{\theta}'_{i,t-1} = [\theta_{i,t-1}^H, \theta_{i,t-1}^C, \theta_{i,t-1}^S]$ is the transpose of the column vector of the three child's human capital measures, μ_i is an unobserved individual effect capturing the child's and parental characteristics that are time-invariant between age 6-7 and 8-9 and consisting in a linear combination of μ_i^I and v_i^k for $k = H, C, S$. $\epsilon_{i,t}$ is an idiosyncratic error independent of the explanatory variables which can be defined as a linear combination of $u_{i,t}$, $\eta_{i,t}^H$, $\eta_{i,t}^C$ and $\eta_{i,t}^S$ in model (4). α_0 is the intercept for stage 1, α_1 is the differential intercept for stage 2, and $\boldsymbol{\beta}$, ρ, λ and ψ are the effects of parental human capital, income, childcare and school inputs. $\boldsymbol{\gamma}$ is a column vector containing the parameters of interest γ^H, γ^C and γ^S, which measure the response of parental investments to child's physical health, cognitive and socio-emotional skills.

As Yi et al. (2015) explain, a positive (negative) value of γ^k would imply that parental investments are reinforcing (compensating) in ability of type k. Without introducing additional assumptions on the utility and production functions 1 and 2, the sign of the effect of the child's human capital on parental time investment is ambiguous because parents generally face an inequity-efficiency trade-off when deciding to choose between a compensating or a reinforcing investment strategy. If the human capital production model (2) is such that $\partial h_{k,t}(.)/\partial\theta_{i,t-1}^s \partial I_{i,t} > 0$ for any k and s (i.e. if there is complementarity between the parental investment in stage t and endowment in stage $(t-1)$), then a high human capital endowment at stage $(t-1)$ may increase the productivity of parental investment at stage t.[11] Therefore, in the case of complementarity, parents may decide to adopt a reinforcing strategy and increase their time investment in stage t when the child's human capital at stage

[11] For a definition of complementarity see Cunha et al. (2006); Cunha and Heckman (2007); Cunha and Heckman (2008); Cunha et al. (2010) and Aizer and Cunha (2012).

$(t-1)$ is higher. However, the response of parental investments may also depend on specific parents' preferences captured by the utility function (1). If the marginal utility of parents is diminishing in the child's human capital, i.e. if $\partial U_t / \partial \theta^s_{i,t} \partial \theta^s_{i,t} < 0$ for $s = H, C, S$, then this could lead to parents reducing their investment in reaction to an increase in their child's human capital. If the utility of parents depends on the inequality between their own and their child's endowments because for example they are averse to intergenerational inequity in endowments; then their utility may increase when adopting a compensating investment strategy, namely investing more when their child is performing below their standards and less when he or she is performing above their standards.

To control for the unobserved individual effect μ_i, we adopt a first difference approach (child fixed-effect estimation) which is equivalent to estimating model (5) transformed using first differences

$$\Delta I^{Time}_{i,2} = \alpha_1 + \Delta \boldsymbol{\theta}'_{i,1} \boldsymbol{\gamma} + \Delta Y_{i,2} \rho + \Delta I^{Care}_{i,2} \lambda + \Delta I^{School}_{i,2} \psi + \Delta \epsilon_{i,2}, \tag{6}$$

where $\Delta I^{Time}_{i,t}$ denotes the difference in the time investment between stage t and $(t-1)$, $(I^{Time}_{i,t} - I^{Time}_{i,t-1})$, and similarly for the other variables.

There are two endogeneity issues in the investment model (6). The first is caused by the presence of unobservables in stage 1 that affect parental time investments as well as human capital production in stage 1. In our framework, these unobservables are captured by the idiosyncratic shocks $\eta^H_{i,1}$, $\eta^C_{i,1}$ and $\eta^S_{i,1}$, which are correlated with both $\epsilon_{i,1}$, the error term in the investment model, and the child's health, cognitive and socio-emotional skills in stage 1, $\theta^k_{i,1}$ for $k = H$, C and S. This implies that there is a potential correlation between $\Delta \boldsymbol{\theta}_{i,1}$ and $\Delta \epsilon_{i,2}$ in Equation (6). The second endogeneity issue is caused by a reverse causality problem which depends on the fact that the parental time investment in stage 1 has an effect on the child's health and skills in stage 1. This translates into a potential correlation between $\theta^k_{i,1}$ and $u_{i,1}$ (the error term in Equation (5)) and, as a result, into a potential correlation between $\Delta \boldsymbol{\theta}_{i,1}$ and $\Delta \epsilon_{i,2}$ in Equation (6).

To correct for the consequent biases caused by these two sources of endogeneity we instrument $\Delta \boldsymbol{\theta}_{i,1}$ with $\boldsymbol{\theta}_{i,0}$. This approach is equivalent to the estimation used by Rosenzweig and Wolpin (1988) and Rosenzweig and Wolpin (1995) to solve the issue of endogeneity in a model for childbirth outcomes. The instruments $\boldsymbol{\theta}'_{i,0} = [\theta^H_{i,0}, \theta^C_{i,0}, \theta^S_{i,0}]$ are uncorrelated with

$\Delta\epsilon_{i,2} = \epsilon_{i,2} - \epsilon_{i,1}$ because the child's human capital in stage 0 depends neither on future shocks nor on future parental investments in stages 1 and 2.

We implement this instrumental variable approach by adopting a two-stage least squares estimation whose first stage consists in the estimation of three regressions, one for each of the three measures of human capital, which are specified as follows

$$\Delta\theta^k_{i,1} = \delta^k_0 + \theta^H_{i,0}\delta^k_H + \theta^C_{i,0}\delta^k_C + \theta^S_{i,0}\delta^k_S + \Delta\mathbf{X}'_{i,2}\boldsymbol{\delta}^k_X + \Delta v^k_{i,1}, \tag{7}$$

where $k = H, C$ and S; $\mathbf{X}$ is a column vector containing all remaining control variables in (6), and $v_{i,1}$ is an idiosyncratic error. If there are self-productivity effects in the child's skills and health as assumed by the production model (2) then the child's ability (or health) $\theta^k_{i,1}$ depends on its lagged value $\theta^k_{i,0}$ and potentially also on the lagged values of the other two measures of the child's human capital $\theta^h_{i,0}$ for $h \neq k$, implying that our instrumental variables are relevant.

The presence of other children in the household may bias our estimation because the parental time investment in a child may be affected by the human capital of her siblings. However, the child fixed-effect controls for unobserved siblings' human capital that does not vary between stage 0 and stage 1. In other words, we are controlling for the possibility of having a sibling who is very gifted or, on the contrary, has cognitive, socio-emotional or health issues which are invariant between stage 0 and stage 1. Therefore the omission of the siblings' human capital cause a bias only if there is correlation (conditional on the covariates) between the sibling changes in human capital between stages and the child's human capital at stage 0 (our instrumental variable) and if the difference in parental investments between stage 1 and 2 depends on the difference between stage 0 and 1 in the human capital of other siblings in the household. We think that these two conditions might hold only for extreme changes in the human capital of siblings, which are usually associated with rare events such as a terminal illness. We do control for such type of health shocks of family members in a sensitivity analysis in Section 8 and we find that our main results do not change.

A final remark is needed to explain the consequences of potential zeros observed for the parental time investment measure on our econometric estimation. The presence of zeros is a common issue when measuring time spent in specific activities over a short period as in our case, where parental time investment is observed only in two specific days. In theory we would like to measure the time parents spend with their child over a much longer time period, which is the two-year gap between wave 2 and wave 3 (between ages 6-7 and 8-9). Because of this mismatch between the period of interest and the reference period in our sample, we observe some zeros for the time investments.

This issue is very similar to the problem of zeros observed when measuring the demand for items that are infrequently purchased (see Keen, 1986). Stewart (2013) adapts the infrequent purchase model considered by Keen (1986) and shows that the ordinary least squares estimation of a regression model for the time spent in specific activities provides an unbiased estimation of the effects of the explanatory variables on the time, even in presence of zeros. This consistency result applies also to the case where the linear regression model is estimated controlling for fixed-effect and using instrumental variables, as in our case. Therefore the major consequence of the presence of zeros for our estimation is simply a reduction of its precision.

4 Comparison of our econometric strategy with alternative estimations

Without loss of generality, we consider the following simplified investment model

$$I_{i,t}^{Time} = \alpha_0 + \theta_{i,t-1}\gamma + \mu_i + \epsilon_{i,t}, \tag{8}$$

where $t = 1, 2$ and where we have omitted all explanatory variables except the child's human capital $\theta_{i,t-1}$, which we assume to be univariate, and we have maintained the same notation as in previous section. Our instrumental variable estimation considers the above model expressed in first difference,

$$\Delta I_{i,2}^{Time} = \Delta\theta_{i,1}\gamma + \Delta\epsilon_{i,2}, \tag{9}$$

and then instruments $\Delta\theta_{i,1}$ with the lagged child's human capital $\theta_{i,0}$. The validity of the instrument relies on the independence between $\theta_{i,0}$ and $\epsilon_{i,s}$ for $s > 0$, i.e. that the child's human capital does not depend on future idiosyncratic shocks. We call this our *basic* assumption.

Our child fixed-effect instrumental variable estimation (FE-IV) is equivalent to adopt a Generalized Methods of Moments (GMM) estimation, which relies on 7 moment conditions entailed by the investment models,

$$I_{i,1}^{Time} = \alpha_0 + \theta_{i,0}\gamma + \mu_i + \epsilon_{i,1}, \tag{10}$$

$$I_{i,2}^{Time} = \alpha_1 + \theta_{i,1}\gamma + \mu_i + \epsilon_{i,2}. \tag{11}$$

The 7 moments conditions are derived by considering the second moments of the observed variables, $I_{i,t}^{Time}$ and $\theta_{i,t}$, and by using the models (10) and (11), under the basic assumption of no correlation between the idiosyncratic error in t, $\epsilon_{i,t}$, and the child's human capital in $(t-1)$. These 7 moment conditions are:

$$\sigma_{I_1}^2 = \gamma^2\sigma_{\theta_0}^2 + \sigma_{\mu}^2 + \sigma_{\epsilon_1}^2 + \sigma_{\theta_0\mu}\gamma, \tag{12}$$

$$\sigma_{I_2}^2 = \gamma^2\sigma_{\theta_1}^2 + \sigma_{\mu}^2 + \sigma_{\epsilon_2}^2 + \sigma_{\theta_1\mu}\gamma, \tag{13}$$

$$\sigma_{I_1 I_2} = \gamma^2\sigma_{\theta_0\theta_1} + \sigma_{\theta_0\mu}\gamma + \sigma_{\theta_1\mu}\gamma + \sigma_{\mu}^2 + \sigma_{\theta_1\epsilon_1}\gamma, \tag{14}$$

$$\sigma_{I_1\theta_0} = \gamma\sigma_{\theta_0}^2 + \sigma_{\theta_0\mu}, \tag{15}$$

$$\sigma_{I_2\theta_0} = \gamma\sigma_{\theta_0\theta_1} + \sigma_{\theta_0\mu}, \tag{16}$$

$$\sigma_{I_1\theta_1} = \gamma\sigma_{\theta_0\theta_1} + \sigma_{\theta_1\mu} + \sigma_{\theta_1\epsilon_1}, \tag{17}$$

$$\sigma_{I_2\theta_1} = \gamma\sigma_{\theta_1}^2 + \sigma_{\theta_1\mu}, \tag{18}$$

where $\sigma(.)^2$ and $\sigma(. \quad .)$ denote the variances and covariances, e.g. $\sigma_{I_t}^2$ is the variance of the investments at time t while $\sigma_{\theta_0\mu}$ is the covariance between θ_0 and the unobserved individual effect μ.

Notice that μ is by definition uncorrelated with the idiosyncratic error, but we allow it to be correlated with the child's human capital. The idiosyncratic error in t, $\epsilon_{i,t}$, is allowed to be correlated with the child's human capital in t but it is assumed uncorrelated with the child's human capital in $t-1$ (our basic assumption). Because in the above system of 7 equations there are only 7 unknown parameters $(\gamma, \sigma_{\mu}^2, \sigma_{\epsilon_1}^2, \sigma_{\epsilon_2}^2, \sigma_{\theta_0\mu}, \sigma_{\theta_1\mu}, \sigma_{\theta_1\epsilon_1})$, the system can be solved by adopting a GMM estimation which imposes the equality between the sample and population moments (see Rosenzweig and Wolpin, 1995 and Del Bono et al., 2012).

The fixed-effect instrumental variable estimation and the GMM estimation are equivalent because they both impose the same basic assumption and, contrary to other alternative estimation methods, they do no impose $\sigma_{\theta_0\mu}$, $\sigma_{\theta_1\mu}$, $\sigma_{\theta_0\epsilon_1}$ and $\sigma_{\theta_0\theta_1}$ to be equal to zero. The equivalence between the GMM and the fixed-effect instrumental variable estimation estimation has been already emphasized by Rosenzweig and Wolpin (1995) and Del Bono et al. (2012), who consider a different type of empirical application. They use repeated observations across siblings rather repeated observations for the same child across time and consider the reverse relationship.

Our FE-IV estimator converges in probability to

$$plim \quad \hat{\gamma}_{FE-IV} = \frac{\sigma_{\Delta I_2, P_{\theta_0}\Delta\theta_1}}{\sigma_{\Delta\theta_1, P_{\theta_0}\Delta\theta_1}} = \frac{\sigma_{\Delta\theta_1, P_{\theta_0}\Delta\theta_1}}{\sigma_{\Delta\theta_1, P_{\theta_0}\Delta\theta_1}}\gamma + \frac{\sigma_{\Delta\epsilon_2, P_{\theta_0}\Delta\theta_1}}{\sigma_{\Delta\theta_1, P_{\theta_0}\Delta\theta_1}}, \tag{19}$$

where P_{θ_0} is the projection matrix onto the space generated by θ_0. This estimator is consistent because the basic assumption implies that $\sigma_{\Delta\epsilon_2, P_{\theta_0}\Delta\theta_1} = 0$ so that $plim \quad \hat{\gamma}_{FE-IV} = \gamma$.

Contrary to the fixed-effect instrumental variable estimation, the estimation of the γ parameter by using the pooled ordinary least squares (POLS) or a fixed-effect (FE) estimation without instruments would be consistent only if additional assumptions are imposed. In particular the consistency of the POLS estimator,

$$plim \quad \hat{\gamma}_{POLS} = \frac{\sigma_{I_t\theta_{t-1}}}{\sigma^2_{\theta_{t-1}}} = \gamma + \frac{\sigma_{\mu\theta_{t-1}}}{\sigma^2_{\theta_{t-1}}}, \tag{20}$$

requires that $\mu = 0$, i.e. there are no relevant omitted time invariant variables, or, if $\mu \neq 0$, that $\sigma_{\theta_0\mu} = \sigma_{\theta_1\mu} = 0$; whereas the consistency of the FE estimator,

$$plim \quad \hat{\gamma}_{FE} = \frac{\sigma_{\Delta I_2\Delta\theta_1}}{\sigma^2_{\Delta\theta_1}} = \gamma + \frac{\sigma_{\Delta\epsilon_2\Delta\theta_1}}{\sigma^2_{\Delta\theta_1}} = \gamma - \frac{\sigma_{\epsilon_1\theta_1}}{\sigma^2_{\Delta\theta_1}}, \tag{21}$$

requires that $\sigma_{\theta_1\epsilon_1} = 0$.

The presence of measurement error in the human capital measure θ_t can bias the FE-IV estimation as well as the other estimations. Assuming that

$$\theta_t = \theta_t^* + \omega_t, \tag{22}$$

where $t = 0$ or 1, θ_t^* is the true child's human capital in stage t, ω_t is a measurement error identically and independently distributed across children and independent of the true human capital in $(t-1)$ and t and of the error term in the investment model in t and $(t+1)$; then the FE-IV estimation will suffer asymptotically of an attenuation bias, i.e.

$$plim \quad \hat{\gamma}_{FE-IV} = \frac{\sigma_{\Delta I_2, P_{\theta_0}\Delta\theta_1}}{\sigma_{\Delta\theta_1, P_{\theta_0}\Delta\theta_1}} = \gamma[1 - \frac{\sigma_{\Delta\omega_1, P_{\theta_0}\Delta\theta_1}}{\sigma_{\Delta\theta_1, P_{\theta_0}\Delta\theta_1}}]. \tag{23}$$

If ω_1 follows an autoregressive process of order 1, $\omega_1 = \eta\omega_0 + \nu_1$, where ν_1 is a random error identically and independently distributed across time and children and independent of θ_0^*, θ_1^*, ϵ_1 and ϵ_2; then

$$plim \quad \hat{\gamma}_{FE-IV} = \gamma[1 - \frac{(\eta - 1)^2 Var(\omega_0)}{\sigma_{\Delta\theta_1, P_{\theta_0}\Delta\theta_1}}]. \tag{24}$$

Therefore the asymptotic bias of the FE-IV estimation is decreasing with the correlation between ω_1 and ω_0 and disappears if the measurement error is perfectly correlated between stage 1 and 0, i.e. if $\eta = 1$.

The above derivation of the asymptotic biases can be easily extended to an investment model with covariates by simply replacing I_t and θ_{t-1} with $M_X I_t$ and $M_X\theta_{t-1}$ where M_X is the annihilator matrix, i.e. the projection matrix onto the space orthogonal to the space spanned by the columns of X which is the matrix of covariates in the model of investments at time t.

5 Data

Our analysis relies on the first three waves of the Longitudinal Study of Australian Children (LSAC), an ongoing biannual survey that collects information on two nationally representative samples of two cohorts of Australian children since 2004.[12] The two samples of children are cohort B (baby), which follows 5,107 children aged 0-1 in 2003-2004, and cohort K (kindergarten), which follows 4,983 children aged between 4-5 in 2003-2004.

The LSAC collects information on the time children spend in different activities using time-use diaries. Furthermore, it provides detailed information on children's health, cognitive and socio-emotional skills, family characteristics and socio-economic background. These details are obtained through interviews with parents who live with the child, teachers, carers as well as using tests administered to children.

In our analysis we only use the sample of children belonging to cohort K because for these children we can observe measures of parental time investment and child's human capital, which are comparable across time.

[12] The two samples have been drawn from the full population of children included in the Medicare Australia enrolment database. More details on the sample design can be found in Soloff et al. (2005) and Gray and Smart (2009).

5.1 Sample selection

Our original sample of children whose parents reported information in both the time use diaries includes 2,221 children.[13] Among them, we restrict the sample to include only children living in intact families, i.e. living with both biological parents (2,021 children). Because our empirical results are based on child fixed-effect methods that require at least three observations for each child, we use a balanced panel sample of children who have been observed in all the first three waves i.e. when they are 4-5, 6-7 and 8-9 years old (1,798 children). Finally, we drop children with missing observations in any of the explanatory variables used in our main analysis, which leaves us with a *main sample* of 1,510 children.

In addition to the main sample, we also consider an *ordinary-day sample* that includes only children for whom the time-use diaries were filled in ordinary days, i.e. excluding unusual days such as holidays and days when the child or other family members were sick. When restricting the sample to children with time diaries which were filled in ordinary days for both the working and weekend day and in both waves, the sample size reduces to 267. In our empirical application we also run a set of sensitivity analysis where we consider alternative measures of child's human capital which are not observed for all 1,510 children. In these specific sensitivity the sample sizes decrease of a maximum of 30%.

5.2 Time-use diaries and parental investments

One of the main advantages of using the LSAC is the availability of time-use diaries (TUDs) that can be used to measure the amount of time fathers and mothers spend with their children doing formative activities.[14] For each of the first three waves the LSAC collects details on the activities done by the child in two randomly assigned days, a working and a weekend day, by asking the main respondent (usually the mother) to complete two 24-hour time-use diaries. More precisely, the main respondent is asked to report the main activity done by the child (by choosing from a list of 26 pre-coded activities), where the activity took

[13]The time investment measure is derived by using details on two diaries collected for each child in a weekend and in a working day. We exclude those cases where only weekend or working day diaries were filled.

[14]Previous papers that have measured parental investments using time diaries include Stafford and Yeung (2004), Hsin (2007), Price (2008), Carneiro and Rodrigues (2009), Hsin (2009), Fiorini and Keane (2014),Del Boca et al. (2014), Del Boca et al. (2016).

place and who was together with the child for each 15-minute interval in a 24-hour day (for a total of 96 consecutive intervals).

In the following, we provide details on our definition of parental time investment using variables collected through the TUDs.

Parental time investment is defined as the time parents spend actively engaged with their child in formative activities, i.e. activities that can benefit child development (see Del Boca et al., 2014). We consider as parental time investment, the time the child spends with (a) the mother only (i.e. without the father), (b) the father only (i.e. without the mother) or (c) both the parents. Parents are defined to be actively engaged only if they are present while the activity takes place and if either the child is the primary focus of the activity or the activity is presumably involving a reasonable amount of interactions between the parents and the child (see Stafford and Yeung, 2004 and Price, 2008). Examples of activities that we exclude because either the activity is not formative enough or it does not require an active engagement of the parent include sleeping, watching television, listening to radio, playing video-games and traveling. While we include both home and out-of-home activities, we exclude time spent in school.

We also exclude time parents spend with their child if other adults (e.g. the child's grandparents) were present at the time of the activity.[15]

We classified formative activities into five categories: eating together, helping with chores, socialising activities, psychological support and educational activities. We compute the sum of the total number of minutes the child spends in each of these formative activities in presence of her parents in a randomly assigned working day (working day time) and in a randomly assigned weekend day (weekend day time) and we define the weekly parental time investment as the working day time multiplied by five plus the weekend day time multiplied by two.

Table 1 shows the amount of time children spend with their parents in each of the above five types of activity and how it changes between waves 2 and 3 when children are 6-7 and 8-9 years old. Overall, parents invest an average of 14.6 hours in a week (875.91 minutes) in formative activities with their 6-7 year-old child, and the time investment remains quite

[15]Further details on the definition of parental time investment we employ in the analysis are reported in Appendix A.

stable over time (856.40 minutes when children are 8-9 years old). Of the weekly time spent in formative activities with parents, 6-10% is spent in psychological supporting activities such as cuddling, hugging and comforting. The remaining time is fairly equally distributed across eating, visiting people and more strictly formative activities such as reading and helping with chores.

5.3 Child's skills and health

In our analysis, we follow the approach of Borghans et al. (2008), Cunha et al. (2010), and Almlund et al. (2011) and we allow for multiple dimensions of human capital. In particular, we focus on the child's cognitive and socio-emotional skills and physical health measured in each of the first three waves of the LSAC.

We measure the child's cognitive skills using the Peabody Picture Vocabulary Test (PPVT - III), which has been administered to the LSAC children in a version adapted for Australia and based on work done in the United States for the Head Start Impact Study. This test is specifically designed to assess the child's verbal ability and scholastic aptitude and to capture real changes in the child's functioning rather than just changes in position relative to peers (Dunn and Dunn, 1997; Rothman, 2005).[16] The PPVT is age specific and includes different, although overlapping, sets of items for children of different ages. Higher scores indicate higher levels of children's cognitive skills.

We use the Strengths and Difficulties Questionnaire (SDQ) composite difficulty score to measure the child's social and emotional skills (Goodman, 1997). The SDQ consists of 25 questions, which the main respondent answers, organized around five major sub-scales: hyperactivity, emotional symptoms, conduct problems, peer problems and pro-social behaviour. Each sub-scale is measured using five items. Following the literature (e.g. Del Bono and Ermisch, 2009; Morefield et al., 2011; Conti and Heckman, 2014), we use responses to 20 questions from the first four components, which are aggregated to form a single "difficulty" score. To ease the interpretation of our findings, we re-code this score so that a higher value represents better socio-emotional skills.

[16] In Appendix B we provide additional details on this measure of cognitive ability.

The child's health is measured by the physical health sub-scale of the Pediatric Quality of Life Inventory (PEDS QL), which is composed of eight items measuring motor coordination and general health (see Varni et al., 1999). The composite score we use is scaled to range from 0 (poor) to 100 (good).[17]

We standardize each of the three above scores, separately by child's stage, to have mean 0 and standard deviation 1.

Table 2 summarizes descriptive statistics for the child's skills and health, reporting both the standardized and raw values of these measures (see top and bottom panel, respectively). Because the standardization of the scores is carried out using the full sample of children responding at each stage while the descriptive are reported for our sample of 1510 children, the standardized scores have a mean very close but not exactly equal to 0 and a standard deviation of about 1. We also measure the correlation between the different dimensions of the child's human capital (using standardized scores) and we find that generally it is low and not always significant. In particular, while emotional skills are positively and significantly correlated with both cognitive skills and physical health (Pearson coefficients are 0.11 and 0.29 respectively), physical health does not appear to be significantly correlated with cognitive skills. These findings confirm the importance of including in the model separate measures of the child's skills that account for the multidimensionality of human capital.

5.4 Additional variables

In the top panel of Table C1 in Appendix C we report descriptive statistics for the time variant covariates, obtained by averaging them across the child's life stages 1 and 2 (age 6-7 and 8-9). The covariates include measures of school quality, family exogenous shocks, income and childcare.

The yearly household income, equivalised to account for the household composition by using the OECD modified scale[18], is on average equal to 39,689 Australian dollars.

Family shocks are defined using four dummies indicating whether, in the year before the interview, the child has experienced a serious illness, injury or assault (which we call 'serious

[17] See Appendix B for more details on these measures.

[18] The OECD modified scale is equal to $(1 + 0.5 * nadults + 0.3 * nchildren)$ with $nadults$ and $nchildren$ measuring the numbers of adults and children in the household.

health issue') directly affecting (i) one of the parents, (ii) close relatives; or a death of (iii) grandparents or siblings, (iv) other family members or close family friends. 6.5 per cent and 10.3 per cent of children in the sample have experienced a serious health issue of one of the parents and of close relative or family friends. About 3.7 per cent of children have experienced the death of a grandparent or sibling; while 18.5 per cent had a close family friend or relative that died.

Finally, we measure childcare inputs using a set of four variables. We consider whether the main childcare arrangement is formal care, informal care or parental care only by defining two dummy variables, taking value one in case of formal and informal childcare respectively (parental care only is the left out reference category). We also add information on the number of hours spent in formal (informal) care for those children whose main arrangement is formal (informal) care. The number of hours is measured as deviation from the average hours computed considering all children for whom formal (informal) childcare is the main arrangement in a specific child's stage. The main childcare arrangement is informal care for almost one in five children, formal care for 15.3 per cent, and parental childcare for the remaining 67 per cent of children.

The bottom part of Table C1 in Appendix C shows the mean and standard deviations for selected time-invariant child's and mother's variables.[19] In our sample, about 50 per cent of children are male, they live in households with an average of 2.6 children, and 14 per cent of them have been admitted to neonatal intensive care unit at birth. Mothers' socio-economic status is proxied by education level, while employment status is included as a measure of time constraint that affects the amount of time mothers can spend with their children. 40 per cent of mothers have at least a university degree, and 24 per cent are inactive or unemployed.

6 Main results

Table 3 shows the estimates of the investment model (5), where the dependent variable is the weekly parental time investment measured in minutes and the set of explanatory variables includes (i) three measures of the child's human capital (physical health, cognitive

[19]For the purpose of our analysis, we consider mother's education and employment status as time invariant and we measure these variables in child's stage 2, when children are 8-9 years old.

and socio-emotional skills) standardized to have a mean of zero and a variance of one, (ii) equivalised household income and (iii) childcare inputs (two dummies indicating whether formal or informal childcare is the main childcare arrangement, and the amount of hours the child spends in the main type of childcare, expressed as deviation from the mean). We do not include measures of the parents' human capital, θ_i^P. However, this does not bias our results because we consider a child fixed-effect estimation computed using the first difference between two consecutive life stages of the child, i.e. between age 6-7 and 8-9, and changes in parents' human capital are unlikely to occur in the two-year gap between these two stages. Similarly, we do not include measures of school inputs because there is very little or no variation across time of the primary school characteristics which we can observe (e.g. type of school - public, Catholic or independent school- number of pupils, pupil-teacher ratio, and teachers' work experience). All children are enrolled in primary school in stage 1 and 2 when they are between 6 and 9 years old.

In the first column, we report results obtained using child fixed-effect estimation without instrumental variables (child FE), which seem to suggest that parents adopt a compensating behavior for changes in the child's socio-emotional skills. However, these results are likely to be biased by (i) a reverse causality issue, i.e. the fact that the parental investment in a stage can affect the child's human capital in the same stage; (ii) an endogeneity issue caused by unobserved time-variant variables that affect both the parental investments and the child's human capital in the same stage. For this reason we consider also the child fixed-effect estimation obtained instrumenting the first differences of the three measures of child's human capital with the twice-lagged measures of human capital (child FE estimation with IVs). When using such instrumental variable estimation we find that parents adopt a reinforcing behaviour for changes in their child's socio-emotional skill, they compensate for changes in their child's physical health and are indifferent to changes in their child's cognitive skill. In particular, one standard deviation increase in the child's socio-emotional skills leads to an 128-minute increase in the weekly time investment (see the second column of Table 3), while for one standard deviation decrease in the child's physical health parents raise their time investment by about 63 minutes. The endogeneity test (a robust Durbin-Wu-Hausman test) has a p-value of 0.016, which confirms that there is an endogeneity issue which biases the child fixed-effect estimation; therefore our preferred estimation is the one which employs instrumental variables. Looking at the effect of the remaining covariates, we find that parental time investment does not seem to react to changes in the household financial resources measured by the equalized household income but depends on the amount of childcare. In particular, an increase in the amount of hours of formal or informal childcare has a negative impact on the parental time investment, which is statistically significant at 10% level. Nevertheless, formal and informal child care are not a perfect substitute for parental time and indeed one hour of additional formal or informal child care leads only to a reduction of weekly parental time by about 20 minutes. This result suggests that there is variation in the parental time investment which is not directly explained by variation in the time a child spends in formal and informal child care. Furthermore, omitting to control for child care leads to same estimated response of parental time investments to changes in the child's human capital (see Table C2 in Appendix C). This implies that there is very little or no correlation between the amount of child care and the lagged child's human capital, i.e. parental decisions about child care do not seem to react to changes in the child's human capital.[20]

In the bottom panel of Table 3, we provide evidence of the relevance of our instruments. We report the F-tests for the joint significance of the instruments in the first stages, i.e. in the regression of each of the three measures of human capital on the instruments, while controlling for child fixed-effects and covariates (see Table C3 in Appendix C for the full set of first stage results). Given the large F-statistics, we strongly reject the assumption of a zero effect of the instruments in each of the first stage equations. Further evidence in support of a strong relevance of our instruments is provided by Shea's partial R-squared, which are above 0.20 for all the three first stages.

If the parental time investment has a positive effect on child's human capital as Equation (21) suggests, then the child FE estimation without IVs underestimates the effect of the child's human capital with respect the FE estimation with IVs (see Equation (2)). We find this to be the case for socio-emotional skills, suggesting that parental time investments has a positive feedback effect on socio-emotional skills of their child.

The compensating effect we find for changes in the child's physical health are unsurprising and in line with some previous studies (e.g. Yi et al., 2015). Indeed, we expect parents of a child in bad health to increase their time investment in order to take care of their child. On

[20] Results using alternative definitions of parental time investments are reported in Appendix D.

the other hand, the neutral response of parents to changes in their child's level of cognitive skills may be more puzzling. This finding could be explained by parents believing that their time investments are less effective in helping a child to improve her cognitive skills than other types of investments, such as paying for private lessons (e.g. tutoring after school) or for the enrollment fees in a good private school. We test this hypothesis by estimating an investment model where we measure parental investments with the weekly amount of time the child spends taking private lessons (tutoring, music classes, etc.). We regress this variable on the lagged measure of cognitive skills and the same set of controls as in the time investment model. Results obtained using child fixed-effect instrumental variable estimation (reported in Table 4) show that parents compensate for changes in the child's cognitive skills. In particular, for one standard deviation decrease in the child's cognitive skill, children spend 20 more minutes per week engaged in private lessons. This result is in line with recent empirical evidence that parents compensate for low cognitive skills by increasing monetary investments rather than by spending more time with their children (Attanasio et al., 2015a).

A possible explanation for the reinforcing strategy parents adopt for child's socio-emotional skills is the psychic cost associated with parental time investments. The psychic cost may be especially high if the child has serious behavioural problems which make the time parents spend with their child less enjoyable. This may lead parents to spend less time with their child if her socio-emotional skills are low. We check whether this is the case by allowing the response of parental investment to differ between two groups of children: those with and without temper tantrums.[21]. We find that the reinforcing strategy is attenuated for children who have no tantrums, but the difference is not statistically significant (see top panel of Table 5).

The time constraints and the time cost may be especially high for working parents compared to non-working parents and this may affect their time investment decisions. To assess the effect of the time cost we explore the heterogeneity of parental time investment response by working status of the mother (see bottom panel of Table 5). We focus here on the labour status of mothers because almost all fathers in our sample are working. The IV estimation results show that parents compensate for child's cognitive skills if the mother does not work (i.e. if she has less time constraints), while a neutral strategy is found for working mothers,

[21] Children with temper tantrums are children for which the mother reports at least one episode of tantrum in one of the two collected time diaries.

supporting the hypothesis of the time-constraint mechanism as an explanation for parental investment behaviors. We also find that working mothers adopt a reinforcing strategy for changes in their child's socio-emotional skills, while non-working mothers do not seem to react statistically significantly, although the difference in the effect between working and non-working mothers is not statistically significant. The compensating investment response to change in physical health is confirmed for working mothers, whereas for non-working mothers we find a neutral strategy. This seems justified by the fact that, in households where both parents work, the illness of a child leads parents to take some days off and therefore to a more evident increase in the parental time investment than in household where the mother is already at home. However, there is no statistically significant difference in the parental investment response to changes in child's health between working and non-working mothers.

7 Validity of the instrumental variable estimation

The validity of the instruments relies on the assumption of independence between the current child's human capital and the future idiosyncratic shocks affecting parental investments (see basic assumption in Section 4). In our empirical application this translates in an independence assumption between the three measures of child's human capital (cognitive and socio-emotional skills and physical health) observed at 4-5 and the error term in the parental investment equation at age 8-9. Because we control for any time invariant observed and unobserved variable by considering a child fixed-effect estimation, the only reason why our instruments could be invalid is because of unobserved time-varying characteristics which are correlated with the child's human capital measures at age 4-5 as well as with the parental investment at age 8-9. In particular we are concerned that unobserved family shocks such as serious health issues of family members might have an effect on both child's human capital at age 4-5 and on later parental time investment at age 8-9.

Previous research has identified health shocks occurring to parents or other family members as important predictors of child development (Morefield et al., 2011, Adda et al., 2012, Westermaier et al., 2013, and Ryan and Anna, 2015). These shocks might also limit the time parents can spend with their children. We account for these exogenous shocks by adding to the investment model a set of four dummy variables indicating serious health issues occurred to parents, serious health issues occurred to close relatives, death of the child's grandparents or siblings, and death of other family members or close family friends. Column (1) in Table 6 shows results with these additional covariates when using the child fixed-effect instrumental variable estimation. We find that the coefficients associated with these variables are not statistically significant at the 5 per cent level (neither separately nor jointly), suggesting that the parental investment is not affected by exogenous family health shocks, at least as defined in our sample. Comparing the results in Table 6 with our main results in Table 3, we find no relevant differences in the investment strategy of parents, who still reinforce for high socio-emotional skills.

To provide further evidence of the validity of the instrumental variables we use additional instruments in our estimation to compute an over-identifying test (Sargan test). The instruments we employ are the child's human capital measures at age 4-5 and their interactions with a dummy which takes value 1 if the child had neonatal intensive care. These instruments are justified by the fact that a negative health shock at birth might affect the child development process. The estimated coefficients using the additional instruments are reported in column 2 of Table 6 and they do not seem to differ from our benchmark results (Table 3). The Sargan test has a p-value of 0.617, suggesting that we cannot reject the validity of the instruments used in the analysis.

Our instrumental variable estimation could be biased if parental time investments suffer of non-random measurement error. In particular we are concerned that time use diaries are collected in two days which might not represent the typical time interactions between parents and children. This can happen, for example, because diaries are filled during a holiday or when the child or the parent is sick. As a robustness check, we estimate the main models using the subsample including only observations in ordinary days. As shown in Table 6, the effect of an increase in physical health seems to double but the standard errors are quite large and the results are not statistically different.

Another threat to the validity of our instruments can be caused by measurement errors. If our measures of child's human capital have measurement errors, then both the lagged human capital measures (our instruments) and the first difference in the human capital measures (the variables to be instrumented) have measurement errors leading to a bias of the estimation. In the case of measurement errors that are perfectly correlated between age 4-5 and 6-7, the estimation will be unbiased because computing the difference in the child's human capital measures between age 6-7 and 4-5 will eliminate the measurement errors. On the contrary, if there is no perfect correlation between measurement errors at age 4-5 and 6-7, then, under standard assumptions on the measurement errors (see Section 4), it is possible to prove that there is an attenuation bias which in absolute terms is decreasing with the correlation.

To check if there is a substantial bias in our estimation caused by this measurement error, we perform separate factor analyses using two measures of cognitive skills, two of socio-emotional skills and seven of physical health observed when the child is 4-5 to derive latent factors which are theoretically error-free measures of the child's human capital. To derive these factors at 4-5, we use the following scores: a test assessing early literacy and numeracy skills (see De Lemos and Brian, 2000) called Who Am I (WAI); a standardized composite score derived from the Strength and Difficulty Questionnaire (SDQ) administered to teachers; two motor skills measures based on how the child's teacher rates the child's gross and fine motor skills compared to other children of similar age; and three indicators for whether the child needs or uses medicines prescribed by a doctor (other than vitamins), whether the mother has any concern about her child's weight, and whether she thinks that her child uses medical care more often than the average child. We retain one common factor for cognitive skills, one for socio-emotional skills and three for physical health, which explain 63%, 67% and 53% of the total variance respectively. We use these five factors as instruments for the differences in the human capital measures between age 6-7 and 4-5. As these instruments have no measurement errors, the estimation does not suffer from the measurement error problem. Results are reported in column (1) of Table 7 and are in line with our main results except for an increase in the standard errors. Because we are using five factors to instrument three variables we can test the validity of our instruments by using the Sargan test. The p-value of this test is 0.617 suggesting that these factors are valid instruments.

An approach to correct for measurement error on socio-emotional skills consists in using the information available from the Strength and Difficulty Questionnaire (SDQ) administered to mothers (our main measure of child's socio-emotional skill) together with the SDQ score reported by the teacher. We replace the SDQ score reported by the mother with the average of the SDQ scores reported by the mother and the teacher. Under the classical measurement error assumptions, i.e. under the assumption that the measurement errors of the two SDQ scores are uncorrelated with each other and uncorrelated with the true chid's socio-emotional skills, the measurement error bias should halve. The fact that empirically we find very similar results when using the SDQ score reported by the mother and when using the average of the two SDQ scores (see column 2 in Table 7) seems to suggest that the bias caused by the measurement error is not a major concern when using the child fixed-effect instrumental variable estimation.

To further convince ourselves that the measurement error issue is not a major concern, we replace the SDQ score reported by the mother with the one reported by the teacher, which might be a more objective measure and therefore be less affected by measurement error. We still find very similar results for the effect of socio-emotional skills (see column 3 in Table 7). These results suggest also that mothers' beliefs on the socio-emotional skills of their child are not systematically different from the teachers' beliefs.

Because we measure child's cognitive skills using an objective test administered by the interviewer, the Peabody Picture Vocabulary Test, the statistically insignificant effect of the child's cognitive skills on the parental investment may be caused by the fact that parents have subjective beliefs of their child's cognitive skills which differ from the objective measure. In column 4 of Table 7 we report the estimated response of parental time investment when using a subjective measure of cognitive skill, a dummy taking value 1 if the mother has concerns about her child's receptive language skills. We still find an effect of cognitive skills which is not statistically significant.

Overall, the absence of a large empirical bias caused by measurement errors when using child FE with IVs seems to suggest that the measurement errors in our child's human capital measures are either small in magnitude or quite persistent across time so that taking the difference in the child's human capital measures between two points in time reduces or even cancels out completely measurement errors.

8 The heterogeneity of the mothers' investment behaviour

In this section we explore how the response of the parental time investment varies by socio-economic status as well as by child's gender and by the number of children in the household.

To assess whether the parental time investment strategy differs by socio-economic status, we allow the effects of the child's physical health, cognitive and socio-emotional skills on the parental time investment to vary by parental level of education which we proxy with a dummy indicating whether the mother has a university degree. Because there is a high correlation between maternal and paternal education, this dummy is a proxy for both parents' education. We expect parents with higher education to be more involved in their child's education and to better perceive their child's developmental needs. Additionally, highly-educated parents may also have stronger preferences for child quality, which may lead to larger time investments (Hill and Stafford, 1974, Guryan et al., 2008) and potentially to a stronger compensating strategy. On the other hand, the economic theory suggests that the cost opportunity of spending time with the child is higher for highly-educated parents because of their expected higher productivity in the labour market and their forgone earnings (Becker, 1965), which may lead to reinforcing investments. As a result, whether highly-educated parents adopt a stronger reinforcing or compensating behaviour than low-educated parents is an empirical question. The top panel of Table 8 shows the results for mothers with a university degree and the differential effect for mothers without a university degree, which suggest that there are not statistically significant differences in the parental time investment response by level of education.

Because the time resources of parents are limited, the parental time investment response may be attenuated by the presence of more than one child in the household. To assess this, we estimate an investment model which allows the time investment response to the child's human capital measures to vary between one-child households and households with at least two children. The middle panel of Table 8 reports the results for this model and shows that there are not statistically significant differences in the investment strategies between parents with only one child and with more than one child.

There may also exist differences in parental preferences for child quality by child's gender and these preferences may lead to differences in the investment strategy adopted for sons and daughters. The bottom panel of Table 8 shows the estimation results on the parental time investment response when allowing the effects of the three measures of the child's human capital to differ for sons and daughters. There is not a statistically significant effect of cognitive skills on parental time investment, neither for boys nor for girls, and the difference in the effect by gender is not statistically significant at 5% level. Similarly we do not find a statistically significant difference of the effect of socio-emotional skills by gender, whereas the results suggest that while parents compensate for their daughters physical health they do not react statistically significantly to their sons physical health.

9 Conclusions

This paper provides the first empirical evidence on the response of parental time investments to changes across time in three different dimensions of their child's human capital, which are physical health, cognitive skills and socio-emotional skills. Unlike previous studies that use proxies for parental time investments, we employ information from time-use diaries collected in the Longitudinal Study of Australian Children to derive a direct measure of the weekly amount of time that parents spend with their children in formative activities.

Estimating parental response to the child's skills is challenging because of potential unobservables that may affect both the child's human capital and parental investments and because of the reverse causality. We tackle these issues using the child fixed-effect instrumental variable estimation in a way similar to the approach proposed by Rosenzweig and Wolpin (1995). Furthermore, we show that our approach is robust to a set of sensitivity analysis where we control for measurement errors and for the validity of the instruments.

Our estimates of the parental time investment model reveal some interesting findings. Parents reinforce for socio-emotional skills and compensate for physical health, whereas they do not seem to react significantly to changes in cognitive skills. Nevertheless, we find that parents compensate for low cognitive skills by increasing the time their child spends in private lessons, suggesting that parents believe that the time a child spends with a teacher is more effective than the time she spends with her parents to improve her cognitive skills. There is also some evidence that parents with less stringent time constraints (i.e. when mothers do not work) tend to compensate statistically significantly more for changes in cognitive skills, indicating that time constraints perhaps lead parents to be more concerned about efficiency than equity when choosing their investment strategy. We find also that the reinforcing investment response to changes in socio-emotional skills is attenuated for mothers who work and for children with episodes of tantrums which can increase the time and psychic cost of the investment, but these differences are not statistically significant.

Looking at our heterogeneity analysis results, we do not find any statistically significant difference in the investment response by parental level of education or by number of children. Parental investment strategies do not seem to differ between daughters and sons except for investment response to changes in physical health, which seems to be compensating for girls and neutral for boys.

The child fixed-effect instrumental variable estimation and the child fixed-effect estimation provide different results, especially when looking at the parental investment response to child's socio-emotional skills. Such difference can be explained by the presence of a feedback effect, whereby an increase in parental time investments leads to an improvement in child's socio-emotional skills. On the contrary, we do not find evidence of a feedback effect from parental time investment to cognitive skills and physical health. This may suggest that parental time investments are less effective in fostering child's cognitive skills and physical health than other types of investments, such as school investments and medical care. Which types of parental investments are more productive for child's human capital is an interesting open question that we leave for future research.

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Table 1: Weekly parental time investment (minutes): main sample

Weekly parental time investment: main sample				
	Children aged 6-7 years		Children aged 8-9 years	
	Mean	SD	Mean	SD
Psychological support	89.26	146.05	51.40	111.63
Reading	164.86	168.85	138.74	172.28
Helping with chores	97.65	140.58	116.96	164.77
Eating	229.14	180.85	239.19	181.32
Visiting	294.99	466.42	310.12	497.76
Total time	**875.91**	**580.96**	**856.40**	**593.96**
No. children	1,510		1,510	

Table 2: Descriptive statistics of child's human capital measures by child's age

	Standardized Variable			
Variable	Mean	SD	Min	Max
Cognitive skills				
4-5 years old	0.0369	0.9892	-2.4023	3.4543
6-7 years old	0.0386	0.9760	-4.7942	3.3771
8-9 years old	0.0653	0.9506	-4.6429	3.7032
Socio-emotional skills				
4-5 years old	0.0456	0.9706	-3.4760	1.7324
6-7 years old	0.0657	0.9433	-4.9717	1.5158
8-9 years old	0.0621	0.9421	-4.4393	1.3842
Physical health				
4-5 years old	0.0471	0.9306	-4.4316	1.5577
6-7 years old	0.0384	0.9544	-4.6777	1.2203
8-9 years old	0.0487	0.9468	-5.1873	1.1674

	Raw Variable			
	Mean	SD	Min	Max
Cognitive skills				
4-5 years old	65.6405	5.5407	51.9777	84.7821
6-7 years old	74.7944	4.9058	50.5028	91.5754
8-9 years old	79.4702	4.5764	56.8045	96.9832
Socio-emotional skills				
4-5 years old	8.4205	4.8453	0	26
6-7 years old	6.9291	4.507664	0	31
8-9 years old	6.5841	4.6916	0	29
Physical health				
4-5 years old	83.4488	10.1962	34.375	100
6-7 years old	83.7180	13.1478	18.75	100
8-9 years old	84.9111	12.7710	14.2857	100

Notes. All statistics are computed using the main sample and pooling together the observations when children are 6-7 and 8-9 years old. The standardized variables are obtained by rescaling the raw scores to have mean zero and standard deviation 1. The raw socio-emotional variable measures child's behavioural problems, therefore a higher score implies more socio-emotional problems. On the contrary, the standardized socio-emotional variable is recoded and standardized to be higher for children with better socio-emotional skills.

Table 3: Model for parental time investment

	Child fixed-effect estimation	
	without IV	with IV
Cognitive skills	24.046	-21.668
	(17.978)	(32.791)
Socio-emotional skills	14.479	118.151***
	(22.008)	(45.091)
Physical health	-42.468**	-62.979*
	(19.528)	(38.084)
Income	-0.000	-0.000
	(0.001)	(0.001)
Hours of informal care	-20.099*	-20.206*
	(10.285)	(10.547)
Hours of formal care	-22.431*	-21.533*
	(11.620)	(11.710)
Mainly using informal care	66.885	79.052
	(62.155)	(63.825)
Mainly using formal care	71.918	63.040
	(75.774)	(76.583)
Constant	854.532***	-25.689
	(47.512)	(19.776)
First stages - statistics		
Cognitive skills	-	219.0
Socio-emotional skills	-	154.3
Physical health	-	175.9
Endogeneity test (p-value)	-	0.016
No. observations	3,020	3,020
No. children	1,510	1,510

Notes. *** p <0.01, ** p <0.05, * p <0.1. Standard errors are reported in parentheses. The instruments variables (IV) used for the estimation results reported in column 2 are the twice-lagged skills.

Table 4: Model for monetary investment (lessons)

	Child fixed-effect estimation	
	without IV	with IV
Cognitive skills	0.063	-19.138*
	(6.356)	(11.562)
Income	0.001	0.000
	(0.000)	(0.000)
Hours of informal care	-5.750	-2.959
	(3.635)	(3.691)
Hours of formal care	4.562	3.762
	(4.109)	(4.102)
Mainly using informal care	35.925	19.746
	(21.976)	(22.354)
Mainly using formal care	-11.224	-1.629
	(26.791)	(26.816)
Constant	32.829*	24.438***
	(16.792)	(6.923)
First stages - statistics		
Cognitive skills	-	645.3
Endogeneity test (p-value)	-	0.048
No. observations	3,020	3,020
No. children	1,510	1,510

Notes. *** p <0.01, ** p <0.05, * p <0.1. Standard errors are reported in parentheses. The instrumental variables (IV) used for the estimation results reported in column 2 are the twice-lagged cognitive skills.

Table 5: Models for parental time investment. Heterogenous effects between children with and without tantrums and by mother's working status

	Child fixed-effect IV estimation	
	Effect for children with temper tantrum	Differential effect for children w/o temper tantrum
Cognitive skills	-8.271	-19.094
	(58.514)	(71.057)
Socio-emotional skills	143.912**	-41.683
	(72.179)	(92.172)
Physical health	-80.480	27.993
	(60.694)	(78.346)
F-test (first stages)		
Cognitive skills	109.9	113.8
Socio-emotional skills	77.32	76.70
Physical health	88.51	86.73
Endogeneity Test (p-value)	0.069	0.069
No. observations	3,020	3,020
No. children	1,510	1,510
	Effect for children with working mothers	Differential effect for children with non-working mothers
Cognitive skills	8.912	-143.339*
	(36.849)	(81.671)
Socio-emotional skills	156.361***	-171.871
	(50.601)	(112.414)
Physical health	-73.403*	79.583
	(42.666)	(96.275)
F-test (first stages)		
Cognitive skills	110.3	97.33
Socio-emotional skills	77.08	70.14
Physical health	87.87	81.95
Endogeneity Test (p-value)	0.058	0.058
No. observations	3,020	3,020
No. children	1,510	1,510

Notes. *** p <0.01, ** p <0.05, * p <0.1. Standard errors are reported in parentheses. All models include the full set of covariates as in Table 3.

Table 6: Model for parental time investment model.
Testing the validity of the instrumental variable estimation

	Child fixed-effect IV estimation		
	Additional family shocks	Overidentified model	Ordinary days
Cognitive skills	-21.070	-21.598	33.915
	(32.699)	(32.772)	(56.542)
Socio-emotional skills	124.096***	118.228***	133.788
	(45.123)	(44.915)	(86.929)
Physical health	-62.986*	-61.938	-128.548*
	(38.096)	(38.018)	(68.055)
F-test (first stages)			
Cognitive skills	220.5	109.5	47.93
Socio-emotional skills	153.6	77.77	23.80
Physical health	175.5	88.18	43.65
Endogeneity test (p-value)	0.011	0.015	0.125
Sargan test (p-value)	-	0.617	-
No. observations	3,020	3,020	534
No. children	1,510	1,510	267

Notes. *** p <0.01, ** p <0.05, * p <0.1. Standard errors are reported in parentheses. Column 1 shows results obtained when we include a set of dummies capturing family health shocks. Column 2 shows results from an overidentified model, where twice-lagged skills as well as their interactions with a dummy for child's neonatal intensive care are used as instruments. Column 3 shows results when we restrict the sample to children whose parents filled the time use questionnaires in ordinary days. All models include the full set of covariates as in Table 3.

Table 7: Model for parental time investment.
Controlling for measurement errors in the child's human capital measures

	Child fixed-effect IV estimation			
	(1)	(2)	(3)	(4)
Cognitive skill	-60.810	-23.918	-19.192	48.402
	(55.841)	(35.827)	(35.703)	(152.447)
Socio-emotioanal skills	147.058*	145.003***	88.713***	113.010**
	(81.812)	(54.904)	(28.923)	(44.427)
Physical health	-15.915	-83.803**	-76.203*	-64.752*
	(73.744)	(41.937)	(42.176)	(37.979)
F-stats (First stages)				
Cognitive skills	42.48	181.3	180.8	167.3
Socio-emotional skills	27.91	122.6	237.2	164.3
Physical health	25.29	146.6	144.4	176.1
Endogeneity test (p-value)	0.195	0.048	0.063	0.054
No. children	1,085	1,275	1,275	1,510
No. observations	2,170	2,550	2,550	3,016

Notes. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Standard errors are reported in parentheses. Column (1) shows results when using as IVs factors extracted from multiple measures of cognitive, socio-emotional skills and physical health at age 4-5. Column (2) shows results when socio-emotional skills are measured by the average SDQ score reported by the mother and the teacher. Column (3) shows results when socio-emotional skills are measured by the SDQ score reported by the teacher. Finally, column (4) shows the results when cognitive skills are measured by a dummy for maternal concerns about receptive language skills. All models include the full set of covariates as in Table 3.

Table 8: Models for parental time investment.
Heterogenous effects by mother's education, presence of siblings and child's gender

	Child fixed-effect IV estimation	
	Effect for children with highly educated mothers	Differential effect for children with low educated mothers
Cognitive skills	-20.642	-0.350
	(51.518)	(66.941)
Socio-emotional skills	204.524***	-130.080
	(78.017)	(96.830)
Physical health	-34.857	-50.259
	(55.429)	(76.910)
F-test (first stages)		
Cognitive skills	109.6	107.6
Socio-emotional skills	77.01	83.33
Physical health	88.25	74.10
Endogeneity Test (p-value)	0.015	0.015
No. observations	3,020	3,020
No. children	1,510	1,510
	Effect for children with siblings	Differential effect for children with no siblings
Cognitive skills	-19.595	-44.612
	(33.781)	(141.734)
Socio-emotional skills	133.428***	-277.003
	(46.441)	(192.787)
Physical health	-61.158	-42.431
	(40.785)	(117.815)
F-test (first stages)		
Cognitive skills	109.4	82.74
Socio-emotional skills	77.13	62.87
Physical health	88.42	168.5
Endogeneity Test (p-value)	0.044	0.044
No. observations	3,020	3,020
No. children	1,510	1,510
	Effect for daughters	Differential effect for sons
Cognitive skills	-77.683	116.623*
	(48.199)	(68.605)
Socio-emotional skills	173.726**	-108.356
	(73.734)	(93.030)
Physical health	-143.423***	154.736**
	(55.271)	(76.756)
F-test (first stages)		
Cognitive skills	109.6	102.1
Socio-emotional skills	79.08	86.72
Physical health	88.38	91.31
Endogeneity Test (p-value)	0.002	0.002
No. observations	3,020	3,020
No. children	1,510	1,510

Notes. *** p <0.01, ** p <0.05, * p <0.1. Standard errors are reported in parentheses. All models include the full set of covariates as in Table 3.

Appendix A: Definition of formative activities

Table A1: List of developmental activities included in the parental time investment measure

Activity Category	List of Activities
Eating	eating, drinking
Educational Activities	read a story, talked/sung to, sing/talk
Helping with chores	helping with chores, job
Socialising Activities	visiting people, special events, party
Psychological Support	holding, cuddling, hugging, comforting, soothing

As defined in Section 5, our measure of parental time investment is the weekly time the child spends in any of the formative activities listed in Table A1 in presence of one or both parents and it is derived from the LSAC time-use diaries.

Differently than other time use diaries surveys (such as the one in the Child Development Supplement of the Panel Study of Income Dynamics), the LSAC does not distinguish among primary and secondary activities and between activities with parents actively and passively engaged. In the following we explain how we deal with the issue of classifying multiple activities done contemporaneously and how we discern between actively and passively engagement of parents.

When two or more activities are taking place at the same time, we adopt an approach similar to the one employed in Fiorini and Keane (2014) by ranking the activities in a way which reflects our ordering into primary, secondary, and so on. In particular, we follow the convention that, if a child is engaged in a socialising activity, that activity is classified as the main one. In absence of a socialising activity, the next activity which we classify as the main one is any activity providing psychological support to the child, followed by educational activities (such as reading), helping with chores and finally eating with parents.

To make sure that our definition of time investment does not include time spent by parents without being actively engaged with the child, we define the parental investment as the time mothers and fathers spend with their child doing a restricted list of formative activities (see Table A1), which would typically require the active engagement of an adult. Additionally, in the case of eating activities, we consider the time spent doing such activities only if both parents are present. The idea is to capture only the time the child spends being actively engaged in conversations with her parents. For the same reason, we also exclude the time spent with both parents while eating and/or drinking if at the same time the child was reading a book or playing video-games.

As mentioned in Section 5, we do not include in the parental time investment definition the time the child spends in formative activities with her parents if other adults are present. An exception is constituted by the time spent in social activities; if the child is visiting friends or relatives with her parents, we consider the time spent in those activities as quality time regardless of the presence of other adults.

Appendix B: Definitions of the three child's human capital measures

The **Peabody Picture Vocabulary Test (PPVT)** provides a measure of listening comprehension for spoken words in standard English and a screening test for verbal ability. The main part of the test involves asking the child to select among different pictures the one "... that best illustrates the meaning of the stimulus word presented orally by the examiner" (seee Dunn and Dunn 1997).

The **Strength and Difficulty Questionnaire (SDQ)** is a behavioural screening questionnaire composed of 25 items divided in 5 subscales (peer problems, emotional symptoms, hyperactivity, conduct problems and prosocial behaviour).

The parent who is the main carer of the child is asked to rate each of a set of statements concerning the child as "certainly true" (2 points), "somewhat true" (1 point) or "not true" (0 point). Higher scores indicate more negative symptoms, except for the scores indicating prosocial behaviour. Below we report the questions asked in the SDQ.

- *SDQ Peer problems subscale*: it is the average score for 5 parent-rated items assessing problems in the child's ability to form positive relationships with other children. The 5 corresponding statements about the child are:
  - rather solitary, tends to play alone,
  - does not have at least a good friend,
  - generally not liked by other children,
  - picked on or bullied by other children,
  - gets on better with adults than with other children.
- *SDQ Emotional symptoms subscale*: it is the average score for 5 parent-rated items which are statements on the child's frequency of displaying negative emotional states, which are:
  - often complains of headaches, stomach aches or sickness,
  - many worries, often seems worried,

  - often unhappy, down-hearted or tearful,
  - nervous or clingy in new situations, easily loses confidence,
  - many fears, easily scared.

- *SDQ Hyperactivity subscale*: it is the average score for 5 parent-rated statements about the child's fidgetiness, concentration span and impulsiveness, which are:
  - restless, overactive, cannot stay still for long,
  - constantly fidgeting or squirming,
  - easily distracted, concentration wanders,
  - does not stop and thinks things out before acting,
  - does not see tasks through to the end, poor attention span.

- S*DQ Conduct subscale*: it is the average score for 5 parent-rated items assessing child's tendency to display problem behaviours when interacting with others and the 5 corresponding statements about the child are:
  - often has temper, tantrums or hot tempers,
  - not generally obedient, usually does not do what adult requests,
  - often fights with other children or bullies them,
  - often argumentative with adults,
  - can be spiteful with others.

- *SDQ Prosocial subscale:* it is the average score for 5 parent-rated items assessing the child's propensity to behave in a way that is considerate helpful to others, and the 5 corresponding statements about the child are:
  - considerate of other people's feelings,
  - shares readily with other children,
  - helpful if someone is hurt, upset or feeling ill,
  - kind to younger children,

  - often volunteers to help others.

The **PEDS Physical health subscale** is part of the Pediatric Quality of Life Inventory that measures health-related quality of life in children and adolescents. It integrates a variety of scales that capture different aspects of child's health: physical functioning, emotional functioning, social functioning and school functioning.

We focus on the physical health subscale composed by the following 8 items:

- problems with walking,
- problems with running,
- problems with sports and exercise,
- problems with heavy lifting,
- problems in bathing,
- problems helping to pick up toys,
- problems with hurts or aches,
- problems with low energy levels.

For each of the above items the parent is asked to choose among 5 alternatives to describe the frequency of these problems in the last month: (1) never, (2) almost never, (3) sometimes, (4) often, (5) almost always.

Appendix C: Supplemental Tables

Table C1: Descriptive statistics of control variables

Variable	Mean	SD
Time varying variables		
Equivalised household income	39,689.38	25,540.51
Family shocks		
Serious health issues of parents (dummy)	0.0650	0.2464
Serious health issues of close relatives (dummy)	0.1033	0.3044
Death of grandparents or siblings (dummy)	0.0371	0.1890
Death of other family members or friends (dummy)	0.1851	0.3884
Hours of informal care (deviation from the mean)	-0.1925	2.7457
Hours of formal care (deviation from the mean)	-0.1376	2.6713
Mainly using informal care (dummy)	0.1808	0.3849
Mainly using formal care (dummy)	0.1523	0.3594
Time invariant variables		
Intensive care at birth (dummy)	0.1377	0.3447
Male (dummy)	0.5106	0.5000
No. of children in the household	2.5656	0.9212
Mother with degree (dummy)	0.3980	0.4896
Unemployed or inactive mother (dummy)	0.2444	0.4298
Child with temper tantrum (dummy)	0.3775	0.4849

Notes. Mean and standard deviations (SD) are computed using the main sample. Time invariant variables are computed using information in wave 1, when children are 4-5 years old, except for mother's variable which are measured in wave 3. Statistics of time variant variables are obtained pooling wave 2 and 3 when children are 6-7 and 8-9 years old.

Table C2: Model for parental time investment excluding childcare variables

	Child fixed-effect IV estimation	
	without IV	with IV
Cognitive skills	22.543	-19.582
	(17.970)	(32.922)
Socio-emotional skills	15.535	122.302***
	(22.022)	(45.274)
Physical health	-43.393**	-68.549*
	(19.545)	(38.225)
Income	-0.001	-0.001
	(0.001)	(0.001)
Constant	895.893***	-20.619
	(42.683)	(19.328)
First stages - statistics		
Cognitive skills	-	217.8
Socio-emotional skills	-	154.0
Physical health	-	175.8
Endogeneity test (p-value)	-	0.014
No. observations	3,020	3,020
No. children	1,510	1,510

Notes. *** p <0.01, ** p <0.05, * p <0.1. Standard errors are reported in parentheses. The instruments variables (IV) used for the estimation results reported in column 2 are the twice-lagged skills.

Table C3: First stage regressions for the parental time investment model

	First stage regressions		
	Dependent variable: first difference of		
	cognitive skills	socio-emotional skills	physical health
Double lagged cognitive skills	-0.595***	0.039*	0.039*
	(0.0234)	(0.020)	(0.022)
Double lagged socio-emotional skills	0.0587**	-0.451***	0.072***
	(0.0245)	(0.021)	(0.024)
Double lagged physical health	-0.0583**	0.056**	-0.550***
	(0.0252)	(0.022)	(0.024)
Δ Household income	1.51e-06	0.000	-0.000
	(1.28e-06)	(0.000)	(0.000)
Δ Hours of informal care	0.0212*	-0.005	-0.006
	(0.0125)	(0.011)	(0.012)
Δ Hours of formal care	0.0162	0.008	-0.007
	(0.0140)	(0.012)	(0.013)
Δ Mainly using informal care	0.0298	-0.022	-0.033
	(0.0760)	(0.066)	(0.073)
Δ Mainly using formal care	0.00988	0.011	0.030
	(0.0911)	(0.079)	(0.088)
Constant	0.0203	0.034*	0.015
	(0.0236)	(0.020)	(0.023)
First stages - statistics			
Shea's partial R-squared	0.304	0.241	0.266
F-tests	219.0	154.3	175.9
No. observations	3,020	3,020	3,020
No. children	1,510	1,510	1,510

Notes.*** p <0.01, ** p <0.05, * p <0.1. Standard errors are reported in parentheses. Δ means first difference.

Appendix D: Alternative definitions of time investments

In this section we focus on the time a child spends with the mother and we present results on the response of the mother's time investments obtained using two alternative definitions.

The first definition considers the time the child spends doing any of the formative activities listed in Table A1 of Appendix A but in presence exclusively of the mother rather than in presence of the mother and/or the father.

Such definition of the mother's time investment excludes the time the child spends in recreational and socializing activities in presence of both parents, such as visiting relatives and eating. The estimation results of the mother's time investment model using the child fixed-effect estimation and the child fixed-effect instrumental variable estimation are reported in columns 1 and 2 of Table D1. Mothers seem to adopt a neutral investment strategy, i.e. they do not seem to react to changes in any of the three child's human capital measures.

The second alternative definition still considers the time a child spends doing formative activities exclusively with the mother but enlarges the set of activities by including also personal care activities (e.g. helping with dressing, bathing, hair care and health care) and other less formative activities, which we define as activities that do not necessarily require an active engagement of the mother with the child, such as travelling. Using this definition of mother time investment, we find a more compensating investment response but still not statistically significant (see columns 3 and 4 of Table D1).

Comparing our main results on parental time investments with the ones on maternal time investments, we find two main differences: (i) parental time investments seem to reinforce for changes in the child's socio-emotional skills, whereas maternal time investments do not; (ii) contrary to parental time investments, maternal investments show no evidence of a feedback effect, in particular there is no reverse causality from mother's time investment to the child's socio-emotional skills. One explanation for the absence of this feedback effect is that recreational and socializing activities done with both parents (e.g. visiting friends and relatives, and eating together), which are excluded from the two definitions of mother's time investments, are relevant to foster child's socio-emotional skills more than other activities. Furthermore, results in Table D1 suggest that an increase in the time a mother spends helping her child in every-day activities (such as bathing, dressing, driving to school) does not seem to help her child's development.

Table D1: Model for parental time investment using alternative definitions

	Child fixed-effect estimation			
	without IV	with IV	without IV	with IV
Cognitive skills	1.458	-1.909	-20.747	17.840
	(11.362)	(20.572)	(19.532)	(35.789)
Socio-emotional skills	-7.164	31.103	-59.047**	-49.467
	(13.909)	(28.289)	(23.723)	(48.082)
Physical health	-14.127	-14.832	-24.657	-57.430
	(12.342)	(23.893)	(20.806)	(40.005)
F-stages statistics				
Cognitive skills		219.0		220.6
Socio-emotional skills		154.3		162.0
Physical health		175.9		186.3
Endogeneity test (p-value)		0.491		0.453
No. observations	3,020	3,020	3,168	3,168
No. children	1,510	1,510	1,584	1,584

Notes.*** p <0.01, ** p <0.05, * p <0.1. Standard errors are reported in parentheses. The instruments variables (IV) used for the estimation results reported in columns 2 and 4 are the twice-lagged skills. All models include the full set of covariates as in Table 3.