The response of parental time investments to the child's skills and health

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Abstract

Recent empirical research in family economics has shown the importance of parental investments on human capital development during childhood, but it is still not clear what drives parental investments and, in particular, whether they respond to changes in their child's skills and health. Using the Longitudinal Study of Australian Children we study the behavioural response of parents' time investments to changes in their child's cognitive, socio-emotional skills and health across time. We find that mothers tend to compensate for differences in socio-emotional skills and especially so if they have a low education or if they do not work. On the contrary, mothers with a university degree compensate mainly for differences in cognitive skills. When comparing mothers' and fathers' behaviours, we find that while mothers invest equally in daughters and sons, fathers seem to have a stronger compensating behaviour for sons than for daughters.

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 (Currie and Almond, 2011; Almond and Mazumder, 2013). Most of the empirical literature has focused on the reaction of parental investments to siblings' or 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 time 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 Yi et al., 2016 and Attanasio 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 the first three waves of the Longitudinal Study of Australian Children (LSAC), we take advantage of the availability of time-use diaries to measure the time parents spend with their child doing activities that foster the child's development. Unlike proxy measures of time investment, such as parents' employment status and number of working hours, time-use diaries allow to distinguish between formative and non-formative activities that children do together with their parents and to derive a more accurate measure of time investment.[3] Parental time investment differs from most of the measures of parental investment considered in the empirical literature (e.g. household income and parental employment status) 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.

[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); Restrepo (2012); Rosales-Rueda (2014); Yi et al. (2016).

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

[3] Similar definitions of parental investments based on time-use diaries have been used by Stafford and Yeung (2004), Price (2008), Hsin (2007), Hsin (2009), Carneiro and Rodrigues (2009), Del Boca et al. (2012), Fiorini and Keane (2014) and Del Boca et al. (2014).

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, school inputs and household income. To take into account unobserved heterogeneity and, more specifically, unobserved family and environment characteristics that are time invariant and potentially relevant to explain both child's human capital and parental investments, we use a panel data approach and express our model in first-differences, therefore controlling for child (family) 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 human capital. Specifically, we instrument the first differences in child's skills and health with past measures of skills and health. This fixed effect estimation with instrumental variables is equivalent to the one proposed by Rosenzweig and Wolpin (1995) who identify the effect of maternal prenatal investments on the child's human capital at birth. Instead, we apply it to estimate the reverse causal effect later in life, namely the impact of the child's human capital on parental time investment.

We follow the existing literature on child development by focusing mainly on mothers' time investment behaviours. Mothers are usually the main childcare givers and therefore they are expected to spend more time with their child than fathers, to be more able to detect child's needs and to change their investment accordingly. However, since fathers also play an important role in their child's development, we analyse the difference between mothers' and fathers' behaviours as well as variations in their time investments in sons and daughters.

To assess whether the 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 mother's time investment to vary between mothers with and without a university degree. We expect mothers with a degree to be more involved in their child's education, to better perceive child's developmental needs and therefore to react to such needs by increasing the time spent with their child. Additionally, highly-educated mothers 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 mothers because of their expected higher productivity in the labour market and their forgone earnings (Becker, 1965). As a result, whether they adopt a stronger or weaker compensating behaviour than mothers without a university qualification is an empirical question.

Another important factor that can affect the mother's time investment response is the actual availability of time to invest in her child. Even if the amount of working hours is generally lower than one third of the total amount of hours available in a day, working mothers can face time constraints. This is especially the case for mothers with jobs that do not allow for flexible working time and non-standard working practices, such as working occasionally from home. We check whether mothers who work are actually facing time constraints that limit their time investment response by estimating a model that allows the investment response to change between working and non-working mothers.

Because we consider an investment model with child fixed effects, we implicitly control for the number of children in the household. Even if recent studies on the trade-off between quality and quantity of children (see Becker and Lewis, 1973, and Becker and Tomes, 1976) seem to suggest that the child's human capital does not depend on exogenous shocks to family size (see Black et al., 2005, Angrist et al., 2010), we are still concerned that the investment response to changes in child's human capital might be attenuated in the presence of more children and related time constraints. For this reason we check whether fertility decisions, namely the number of children in the household, affect the parental behavioural response by comparing parental investments in only-child and multiple-child households.

Finally, we carry out a set of sensitivity analyses to (i) test if shocks experienced by the household (such as severe health conditions or death of family members, relatives and close friends) change the parental investment, biasing our results; (ii) assess the effect of measurement errors on time investments by restricting the sample to the cases where the information on time investments has been collected in ordinary days; (iii) check the validity of the instruments by using a larger number of instrumental variables and computing a test of over-identifying restrictions; (iv) investigate whether results change when adopting a semi-log model rather than a linear model.

Results show differences in the response of parental time investments to changes in the three dimensions of the child's human capital. Both mothers and fathers adopt a compensating strategy for socio-emotional skills and are seldom reactive to cognitive skills and physical health. In particular, for one standard deviation decrease in the child's socio-emotional skills mothers (fathers) increase the time spent with their child by about one hour and a half (one hour) per week. Fathers seem to adopt a stronger compensating strategy for sons, whereas mothers' investment strategy does not differ between sons and daughters. Finally, our findings suggest that highly-educated mothers compensate for deficits in cognitive skills, while mothers without a degree compensate for low socio-emotional skills. We find also differences between working and non-working mothers, with working mothers adopting a weaker compensating strategy, which seems to suggest mothers who work face more time constraints.

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 the identification strategy used to produce the empirical evidence on parental time investment. We describe the sample and variables in Section 4 and we report our main results and robustness checks in Sections 5 and 6. Finally, Section 7 concludes.

2 Related 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 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[4] and provides evidence of a compensating behaviour for highly-educated mothers and a reinforcing one (but not statistically significant) for lowly-educated mothers. Restrepo (2012) 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.

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*

[4]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.

endowment (see also Pitt et al., 1990; Rosenzweig and Wolpin, 1995; Del Bono et al., 2012; Aizer and Cunha, 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,[5] find that the mother's investment tends to reinforce for differences in endowments between siblings.

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

[5]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.

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., 2016).

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. (2016) 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 and they seem to be exogenous, at least after controlling for unobserved family effects. 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). The 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, these papers take into account the endogeneity of inputs and, in particular, of parental time 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. (2015) and Attanasio et al. (2015) 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. (2015) 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). In particular they 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 and find that the mother's time investment matters less than the child'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 child has a positive effect on the child'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., 2015) 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. (2015) 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, Attanasio et al., 2015, Del Boca et al., 2014).

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 Becker and Tomes, 1986; Behrman et al., 1982). We assume that parents make decisions in each child's life stage of development, denoted with the subscript t, and that there are S sequential stages between birth and adulthood, $t = 1, ..., T$ (see Del Boca et al.,

2012). 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.[6] 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 is given by

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

[6]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.

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.

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 2006) and 0 for stage 1 (year 2008) 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 is a linear combination of μ_i^I and υ_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. (2016) 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.[7] 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 $(t-1)$ is higher. However, the response of parental investments may also depend on specific parents' preferences captured by the utility function (1). For example, if parents are averse to intergenerational inequity (i.e. to inequalities between their own endowments and the ones of their child), then their utility may increase if 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.

In Section 5, we report empirically the size and the sign of the response of parental time investment to the child's endowments by estimating model 5 using a child fixed effect estimation with instrumental variables as described below.

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

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

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

where $\Delta I_{i,t}^{Time}$ denotes the difference in the time investment between stage t and $(t-1)$, $(I_{i,t}^{Time} - I_{i,t-1}^{Time})$, 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 $\eta_{i,1}^H$, $\eta_{i,1}^C$ and $\eta_{i,1}^S$, 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, $\theta_{i,1}^k$ 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 to a potential correlation between $\theta_{i,1}^k$ and $\epsilon_{i,1}$ and, as a result, on 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 $\boldsymbol{\theta}_{i,0}' = [\theta_{i,0}^H, \theta_{i,0}^C, \theta_{i,0}^S]$ 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

$$\Delta \theta_{i,1}^k = \delta_0^k + \theta_{i,0}^H \delta_H^k + \theta_{i,0}^C \delta_C^k + \theta_{i,0}^S \delta_S^k + \Delta \mathbf{X}_{i,2}' \boldsymbol{\delta}_X^k + \Delta v_{i,1}^k \tag{7}$$

where $k = H, C$ and S; 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) $\theta_{i,1}^k$

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.

A final remark is needed to explain the consequences of potential zeros observed for the parental time investment measure on our econometric strategy. This is a common issue when measuring time spent in specific activities over a short period as in this case, where parental time investment in children 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. More in general 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 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 Australian children since 2004.[8] The two samples of children are called cohort B (baby), which follows 5,107 children from age 0-1, and cohort K (kindergarten), which follows 4,983 children from age 4-5.

[8]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 Gray and Smart (2009) and Soloff et al. (2005).

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 the child's human capital, which are comparable across time.

4.1 Sample selection

Our sample includes only children living in intact families, i.e. children living with both biological parents (93 per cent of the sample). Because our empirical results are based on child fixed effect methods that require at least three observations for each child, we restrict the sample to 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. Finally, we drop children with missing observations in any of the variables used in our analysis, which are: parental time investments in waves 2 and 3 (see Table 1),[9] the child's cognitive and socio-emotional skills and health measured in waves 1 to 3 (see Table 3), and the set of additional control variables described in Table 4, which are measured in waves 2 and 3. This leaves us with a *main sample* of 910 children.

In addition to the main sample, we also consider the *ordinary-day sample* that includes 158 children for whom the time-use diaries were completed in ordinary days, i.e. excluding unusual days such as holidays, days when the child or other family members were sick and so on.

4.2 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

[9]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.

children doing formative activities.[10] 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 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 mother's time investment using variables collected through the TUDs. A similar definition is applied to father's time investment as well.

Mother's time investment is defined as the time she spends actively engaged with her child in formative activities, i.e. activities that can benefit child development (see Del Boca et al., 2014). A mother is defined to be actively engaged only if she is 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 mother and the child (see Stafford and Yeung, 2004 and Price, 2008). We include both home and out-of-home activities, but we exclude time spent in school. Examples of activities that we exclude because either the activity is not formative enough or does not require an active engagement of the mother include sleeping, watching television, listening to radio, playing video-games and travelling.

We classify the formative activities into five categories: eating together, personal care, leisure activities, psychological support and educational activities.[11] We compute the sum of the total number of minutes the child spends in each of these formative activities in presence of the mother in the randomly assigned working day (working day time) and in the randomly assigned weekend day (weekend day time) and we define the weekly mother's time investment as the working day time multiplied by five plus the weekend day time multiplied by two.

Table 1 shows how much time children spend with their mother in each of the above five types of activity and how it changes between waves 2 and 3 when children are 6-7 and

[10] Previous papers that have measured parental investments using time diaries include Stafford and Yeung (2004), Price (2008), Hsin (2007), Hsin (2009), Carneiro and Rodrigues (2009), Del Boca et al. (2012), Fiorini and Keane (2014),Del Boca et al. (2014).

[11] Appendix A provides a more detailed list of formative activities we consider.

8-9 years old. Mothers invest on average more than 14 hours in a week (848 minutes) in formative activities with their 6-7 year-old child, and the investment remains quite stable over time (749 minutes when children are 8-9 years old). Time invested in leisure activities represents about 50 per cent of the overall time investment, while the least time demanding activities seem to be those related to psychological support (about 30 minutes in a week). All mothers spend at least 15 minutes in formative activities with their child except for 6 per cent (9 per cent in wave 3) for whom the time investment is zero.

In Table 2, we compare the time investment of mothers and fathers. We find that fathers spend only 230 minutes doing formative activities with their children, while mothers spend 798 minutes.[12] This evidence is also found in other studies, such as Butcher and Case (1994); Thomas (1990); Thomas (1994); Case and Deaton (1999); Dahl and Moretti (2008), and it suggests that mothers are usually the main care givers, investing almost triple the time of fathers.

The literature has also identified a gender bias in parental investment, with fathers investing more time and financial resources in sons than in daughters (Lundberg, 2005b; Lundberg, 2005a; Lundberg et al., 2007). Yeung et al. (2001) report that fathers spend more time in companionship activities and playing with their sons than with their daughters. Baker and Milligan (2010) find that boys receive more parental time than girls because of a larger time input from their fathers when they are four years old. Our data confirms these results by showing that fathers spend 279 minutes with sons and only 181 with daughters and the difference is statistically significant. On the contrary, mothers are found to invest equally between sons and daughters (772 and 824 minutes respectively).

4.3 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.

[12] Average time investments computed using wave 2 and 3.

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).[13] 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.

The child's health is measured by the physical health sub-scale of the Paediatric Quality of Life Inventory (PEDS QL), which is composed of eight items (see Varni et al., 1999) measuring motor coordination and general health. The composite score we use is scaled to range from 0 (poor) to 100 (good).[14]

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

Table 3 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 910 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

[13] In Appendix B we provide additional details on this measure of cognitive ability.
[14] See Appendix B for more details on these measures.

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 0.10 and 0.27 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.

4.4 Additional variables

In the top panel of Table 4 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.

School quality variables are constructed using data collected from the teacher questionnaire on composition of their classes and the teacher's characteristics. The average pupil-teacher ratio is just over 20 and on average teachers have 16 years of experience.

The yearly household income, equivalised to account for the household composition by using the OECD modified scale[15], is on average equal to 46,743 AUD.

Family shocks are defined using four dummies that report whether *in the year before the interview* the child has experienced a serious illness, injury or assault directly affecting (i) one of the parents or another household member, (ii) a close relative or a family friend; or the death of (iii) a grandparent, a parent or a sibling, (iv) a close family friend or a relative. 5.8 per cent and 10 per cent of children in the sample have experienced a serious illness of one of the household members or of a close relative (or family friend). About 3.7 per cent of children have experienced the death of a grandparent or of another family member; while 18 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

[15]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.

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 76 per of children.

The bottom part of Table 4 shows the mean and standard deviations for selected time-invariant child's and mother's variables.[16] In our sample, about 50 per cent of children are male, they live in households with an average of 2.5 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. 42 per cent of mothers have at least a university degree, and 20 per cent are inactive or unemployed.

We explore the relationship between maternal time investment, her employment status and educational level in Table 5. We find that, in general, unemployed mothers spend more time (806 minutes) with their children compared to employed mothers (734 minutes), although such differences are not statistically significant. Evidence from the previous literature is quite mixed, with some studies showing that mothers tend to reduce time spent on housework and leisure when they experience time constraint, but leave the time devoted to childcare almost unchanged (e.g. Gauthier et al., 2004, Monna and Gauthier, 2008, Guryan et al., 2008), and others indicating a reduction in the time spent with children in the case of working mothers (Baker and Milligan, 2010; Cawley and Liu, 2007). When distinguishing between mothers with a university degree and those without such qualification, we observe that the difference between working and non-working mothers is driven by highly-educated mothers. Among this group, non-working mothers spend in a week 923 minutes with their child, while employed mothers spend only 740 minutes. Instead, for lowly-educated mothers we find a time investment of 729 and 755, respectively. This might depend on the different type of occupation, with more educated mothers being more likely to be employed in jobs which require spending more time working and more flexibility in the working schedule, which, in turn, limits the time they can spend with their children.

[16]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.

Comparing the time investment of mothers with different levels of education, we observe a small difference between the two groups, with more educated mothers investing more time (767 minutes compared to 736 minutes).[17] As suggested by Villena-Roldán and Ríos-Aguilar (2012), this evidence can be confounded by observable characteristics of the two groups of mothers. Indeed, we find a clear gradient among non-working mothers (i.e. mothers who do not face time constraints): those with a university degree invest 923 minutes compared to the 755 minutes that mothers without a degree spend with their children. Differences in the amount of time spent with their children by educational level are also found in Datcher-Loury (1988), Bryant and Zick (1996), Kimmel and Connelly (2007), Sandberg and Hofferth (2001) and Craig (2006).

5 Estimation results

In this section we assess empirically what type of investment strategy parents adopt. We measure parents' time investments as the weekly amount of minutes mothers (fathers) spend with their child in formative activities and we examine whether parents tend to adopt an investment strategy that is reinforcing, compensating or neutral to changes in the child's human capital, measured by physical health, cognitive and socio-emotional skills. Section 5.1 presents our benchmark results for model 5, focusing on the mother's time investment using child fixed effect estimation with instrumental variables. We then extend this model to allow the mother's time investment to vary by her level of education and labour status (Section 5.2). Finally, in Section 5.3, we analyse the father's time investment and we estimate potential differences between mothers and fathers in their investment behaviours for daughters and sons.

5.1 Main results

Table 6 shows the estimates of the investment model 5 where the dependent variable measures the mother's weekly time investment in minutes and the set of explanatory variables includes (i) three measures of the child's human capital (physical health, cognitive skills and socio-emotional skills) standardized to have a mean of zero and a variance of one, (ii)

[17] The difference is not statistically significant at 5 per cent level.

school investments, proxied by pupil-teacher ratio and the teacher's years of experience, (iii) equivalised household income, (iv) 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). Notice that 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 model computed using the first difference between stages and parents' human capital is likely to be constant between two-year gap between the two stages.

In the first column, we report results obtained using child fixed effect without instrumental variables (child FE), while in the second column we report child fixed effect estimation obtained instrumenting the first differences of the three types of the child's human capital with the twice-lagged measures of human capital (child FE with IVs). Results from former specifications are potentially biased by (i) a reverse causality issue, i.e. the fact that the mother's 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 mother's investments and the child's human capital in the same stage. On the contrary, the FE estimation with instrumental variables is theoretically free of biases.

Both estimations suggest that mothers adopt a compensating behaviour for changes in the child's socio-emotional skills, but are indifferent to changes in the child's physical health or cognitive skills. A standard deviation decrease in the child's socio-emotional skills leads to an 89-minute increase in the weekly time investment when considering the FE without IVs, and a 117minute increase when adopting the instrumental variable approach. Based on these results, the endogeneity biases do not seem to be a big concern for the FE estimation without IVs.

Looking at the effect of the remaining covariates, we find the mothers' time investment does not seem to react to school inputs. In particular, changes in the pupil-teacher ratio and in the teacher's years of experience do not lead to any statistically significant effect on the mother's time investment. Differently from school inputs, we do find that the use of formal childcare has a negative impact on the mother's time investment, but only if the amount of hours is above the average observed for children for whom formal care is the main type of childcare arrangement. In particular, one hour of additional formal childcare (with

respect to the average) leads to a reduction of weekly mother's time by about 30 minutes. On the contrary, we find no effect of informal childcare as main childcare arrangement on the mother's time investments. This seems to suggest that formal childcare might be used as a substitute for mother's time investment.

In the bottom panel of Table 6, 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, child fixed effects and covariates (see Table 7 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 and we confirm the strong relevance of our instruments. We also test the endogeneity of the child's skills and health using a robust Durbin-Wu-Hausman test. The robust Hausman statistic and p-value suggest that there is no clear evidence of endogeneity issues (p-value equal to 0.11).

5.2 The heterogeneity of the mothers' investment behaviour

In this section, we explore whether the response of the mothers' time investment varies across mothers with different levels of education and labour status. We start by allowing the effects of the child's physical health, cognitive and socio-emotional skills to differ between mothers with and without a university degree by simply considering an investment model with interactions between the three measures of the child's human capital and a dummy for mothers with a degree. We then consider another model where we allow the effects of the child's human capital measures to differ between working and non-working mothers.

Table 8 shows the results for mothers with different levels of education. Because we do not reject the exogeneity of the child's human capital (the endogeneity test is reported in the last row of Table 8), we focus our discussion on the estimation without IVs (first column in the top panel of Table 8). We find that while mothers with low education show compensating behaviour for socio-emotional skills, highly-educated mothers compensate for a lack of the child's cognitive skills. Evidence of differences in the mother's investment behaviour by educational level are found also in Hsin (2012) and Restrepo (2012), who study the mother's investment response to differences between siblings in birth weight. Using a sibling fixed effect estimation and without controlling for the endogeneity of the investments,

Hsin (2012) finds that highly-educated mothers tend to compensate by spending more time, and especially more educational time, with their lower-birth-weight child. However, she also finds that lowly-educated mothers reinforce for birth weight differences between siblings. Similarly, Restrepo (2012) adopts a sibling fixed effect estimation, but he also controls for prenatal investments (e.g. smoking and drinking during pregnancy) to reduce the potential bias caused by the endogeneity of postnatal investments. He finds that parents with higher (lower) education increase (decrease) cognitive stimulation and emotional support for the child with lower birth weight.

Mothers who work are likely to face time constraints when deciding how much time to invest in their children. Consequently, there might be differences in the time investment behaviour between working and non-working mothers. We have already discussed above (see Section 4) the potential mechanisms leading to differences in the amount of time that working and non-working mothers spend with their child. In Table 9, we show whether these time constraints also change the response of the mother's time investment to variation in their child's human capital. As in the previous estimation results, there is no evidence of an endogeneity bias and therefore we focus on the estimation results without IVs reported in column 1 of Table 9. All mothers seem to compensate for negative changes in the child's socio-emotional skills regardless of their employment status. However, while non-working mothers compensate by spending an additional 165 minutes with their child for a decrease in the child's socio-emotional skills of one standard deviation, working mothers spend only an additional 65 minutes.

5.3 Differences in parents' investments in daughters and sons

As discussed above, there exists evidence of differences in parents' preferences over the gender of their children. These preferences may lead to differences in parental investments between mothers and fathers as well as between sons and daughters. In this section, we assess the presence and size of such differences in the response of parental time investments to changes in the child's human capital.

In columns 1 and 2 of Table 10, we report for comparison our benchmark results for the mother's time investment model using child FE estimation with and without IVs, while in columns 3 and 4 we show the corresponding estimation results when allowing the effects of

the three measures of the child's human capital to differ for sons and daughters. Since the endogeneity bias does not seem to be an issue, we focus on the results reported in column 3 which show that mothers' investments do not depend on child's gender. Their investment strategy is neutral to changes in either daughter or son's cognitive skills and health, while it is compensating for negative changes in socio-emotional skills, with no statistically significant differences between daughters and sons. For one standard deviation decrease in socio-emotional skills, mothers increase their time investment by about one hour and a half for both daughters and sons.

Table 11 reports the same estimation results when considering fathers' rather than mothers' time investments. The endogeneity tests reported at the bottom of Table 11 suggest that we can reject at the 5 per cent level of significance the assumption of no endogeneity. Consequently, the child FE estimations with IVs are preferable and we focus our discussion on the results of such estimations.

Similarly to mothers, fathers do not react to changes in their child's health and cognitive skills, whereas they compensate for decreases in socio-emotional skills (compare column 1 in Table 10 for mothers to column 2 in Table 11 for fathers). Nevertheless, there are also some evident differences in the investment behaviour of mothers and fathers. First, on average, fathers compensate less for negative shocks in their child's socio-emotional skills. For one standard deviation decrease in the child's socio-emotional skills, fathers increase their time investment by about one hour, which is about half of the corresponding effect found for mothers. Second, while there are no differences in this compensating strategy by child's gender for mothers, we find father's compensating effect being statistically significant at the 5 per cent level only for sons (85 minutes). This seems to suggest that while fathers strongly compensate for their sons, they do not react to changes in their daughters' skills.

6 Robustness checks

6.1 Omission of time variant variables

Our benchmark models allow us to estimate the causal effect of the child's human capital on parental time investment accounting for: (i) other types of investments (school, childcare and

household income), (ii) observed and unobserved time invariant characteristics (e.g. parental human capital), (iii) the reverse causality issue (i.e. the fact that parental time investment can have a causal effect on the child's human capital), (iv) the endogeneity issue caused by unobserved idiosyncratic shocks in stage t that can affect both time investment and child's human capital in stage t. However, the response of mother's time investment to changes in the child's human capital could still be biased if there are omitted time-variant variables that are correlated with the child's human capital in stage $(t-1)$ and that are relevant to explain the mother's investment in stage t.

Previous research has identified health shocks occurring to parents or other family members as important predictors of child development (Westermaier et al., 2013, Adda et al., 2012 and Morefield et al. (2011)). These shocks might also limit the time mothers can spend with their children. We account for these exogenous shocks by adding to the investment model a set of four dummy variables indicating the death of a family member, the death of a close relative or family friend, serious illness of a family member, and serious illness of a relative or a close family friend. Table 12 shows results with these additional covariates for the two estimations described above, the child FE estimation without and with instruments. We find that the coefficients associated with these variables are not statistically significant at the 5 per cent level, suggesting that the mother's investment is not affected by exogenous family health shocks, at least as defined in our sample.

6.2 Only-child and multiple-child households

So far our analysis has ignored the presence of siblings in the household and their impact on parental time investments. Because the time available to parents is limited, the presence of other children can lead to a reduction of the parental time invested in each specific child. For multiple-child households our model of parental time investment in a child (see Equation 5) is misspecified because of the omission of his/her sibling's health, cognitive and socio-emotional skills, which parents are likely to take into account when deciding how much time to spend with each of their children.

If we assume that parents who compensate for changes in their child's human capital across time are also compensating for differences in human capital between siblings, and that human capital measures are positively correlated between siblings, then the omission

of the siblings' measures of human capital leads to an attenuation bias of the effect of the child's health, cognitive skills and socio-emotional skills on the parental investment in the child. This is because under the assumption of compensating investments between children and the presence of parental time constraints, a decrease in a sibling's human capital leads parents to invest more in the sibling and less in the child in question.[18]

Because we do not observe information on siblings' human capital, we cannot solve this omission variable issue. However, we are able to estimate model 5, allowing for different parental behaviour according to the number of children present in the household. We find that for one standard deviation decrease in the child's socio-emotional skills mothers compensate by spending 191 minutes more per week with their child when there are no other siblings and 81 minutes more per week if there are other siblings (see Table 13). This result seems to confirm that mothers compensate for changes in the child's socio-emotional skills across time and for differences in socio-emotional skills between siblings.

6.3 Ordinary days

One of the limitations of using time use diaries consists of the fact that days in which the information is collected may be not representative of the parent-child typical time interaction. This can happen, for example, because diaries are filled during a holiday or when the child or the parent is sick. If this is the case, our estimates would be affected by measurement error and potentially biased if the error is correlated with the explanatory variables or the true time investment.

As a robustness check, we estimate the main models using the ordinary-day sample, which includes only information on parental time investments in ordinary days (see Section 4 for more details). As shown in Table 14, results are qualitatively similar to those obtained using the full sample. In particular, mothers appear to increase their time by 139 minutes for a one standard deviation decrease in the child's socio-emotional skills. We find also a reaction of the mother's time investment to changes in the child's physical health, although this reaction is statistically significant only at the 10 per cent level.

[18] A similar attenuation bias would exist if parents adopt an investment strategy that reinforces for differences in human capital between siblings as well as for changes in human capital of the same child across time.

6.4 Alternative distributional assumptions

In Table 15, we introduce some non-linearities in the effect of child human capital on mother's investment by estimating a model where mothers' time investments are expressed in logarithms.[19] In this specification, the estimated coefficients for health, cognitive and socio-emotional skills are interpretable as the relative change in the mother's time investment for one standard deviation increase in the corresponding human capital measure.

The estimation results are in line with our benchmark results. In particular, looking at the child fixed effect estimation results (column 1 in Table 15), we find that for a decrease of one standard deviation in the child's socio-emotional skills the mother increases her time investment by approximately 20 per cent, while her response to changes in the child's health or cognitive skills is not statistically significantly different from zero.

6.5 Overidentified model

We also provide evidence of the validity of our instrumental variables by increasing the number of instruments and computing an over-identifying test (Sargan test). Besides the twice-lagged measures of the child's human capital, we also use their interaction with a dummy for child's neonatal intensive care. These additional 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 16 and do not seem to differ from our benchmark results, which we report, for convenience, in column 1. The Sargan test has a p-value of 0.6486, which suggests that we cannot reject the validity of the instruments used in the analysis.

7 Conclusions

This paper assesses for the first time in the literature whether parental time investments respond 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

[19] To overcome the problem of zero values for the time investment, we add one minute.

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 mothers and fathers spend with their children in formative activities. From a methodological point of view, 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 child fixed effects estimation with instrumental variables in a way similar to the approach proposed by Rosenzweig and Wolpin (1995).

Our estimates of the parental time investment model reveal some interesting and important findings. Both mothers and fathers compensate for low socio-emotional skills by increasing the time they spend with their child doing formative activities. However, when we compare fathers' and mothers' investment behaviours, we find that this effect is larger for mothers than for fathers. In addition, while mothers respond similarly for changes in socio-emotional skills of sons and daughters, fathers adopt a compensating strategy for sons and a neutral strategy for daughters. These findings show that parents are adverse to inequity and adopt investment strategies that compensate for reductions in the human capital of their children, at least in the case of low socio-emotional skills. This evidence, combined with previous research that finds a positive effect of parental investments on children's human capital, suggests that public policies targeted at parents could represent an effective way to improve child development.

We also observe differences in the parental time investment response across mothers with different levels of education and between working and non-working mothers. In particular, working mothers seem to compensate less for low socio-emotional skills than non-working mothers and this might suggest that time constraints working mothers face affect their ability to take care of their children. The implementation of policies that promote family-friendly practices in the workplace, such as working occasionally from home or flexi-time, may allow working mothers to balance work time and time spent with their child.

Additionally, our results show that mothers with a university degree compensate for low cognitive skills and do not react to changes in socio-emotional skills, while mothers without a degree are sensitive to changes in child's socio-emotional skills. Because lowly-educated mothers do not seem to compensate for a decrease in their child's cognitive abilities,

inequalities in cognitive skills across children are expected to be reduced by implementing school policies that raise parental awareness of their child's cognitive performance and of the importance of parental inputs. Schools can play a key role in this context by organizing workshops and events aimed at developing parental skills to support their children's cognitive development and involving parents more directly in their children's education and school activities (see Mayer et al., 2015).

A major question that arise from these findings concerns the identification of the mechanisms explaining such differences in the investment response by mother's education and more in general by socio-economic status. A potential reason could be that lowly-educated mothers are less able to perceive the cognitive needs of their child and consequently compensate less. Another explanation could relate to differences in their expectations and preferences for child *quality*, with highly-educated parents having higher preferences for the child's quality in terms of cognitive abilities. We leave the investigation of these questions for future research.

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Tables

Table 1: Weekly mother's time investment: main and ordinary-day sample

Weekly mother's time investment - main sample				
	Children aged 6-7 years		Children aged 8-9 years	
	Mean	SD	Mean	SD
Educational activities	100.154	138.306	78.165	128.355
Psychological support	31.500	73.636	23.258	69.537
Leisure activities	426.264	444.900	407.440	494.652
Eating	181.582	164.148	160.731	162.836
Personal care	108.478	111.996	78.989	97.353
Total time	**847.978**	**626.343**	**748.582**	**642.938**
No. children	910		910	

Weekly mother's time investment ordinary-day sample				
	Children aged 6-7 years		Children aged 8-9 years	
	Mean	SD	Mean	SD
Educational activities	90.570	111.570	83.259	145.041
Psychological support	21.646	52.360	17.278	55.822
Leisure activities	363.228	341.530	258.418	274.406
Eating	180.570	141.138	162.911	171.440
Personal care	105.570	96.885	86.108	104.996
Total time	**761.582**	**486.268**	**607.975**	**496.651**
No. children	158		158	

Table 2: Parental time investment by child's gender

	Sons	Daughters	Sons and Daughters
Fathers	279.296 (350.945)	181.716 (264.152)	230.077 (313.948)
Mothers	772.300 (652.249)	823.807 (619.860)	798.280 (798.280)

Notes. *** p <0.01, ** p <0.05, * p <0.1. Mothers' and fathers' time investment measured when children are 6-7 and 8-9 years old. Mean time investment in minutes. Standard errors in parentheses.

Table 3: Descriptive statistics of child's human capital measures by child's age

	Standardized Variables			
Variable	Mean	SD	Min	Max
Cognitive skills				
4-5 years old	0.035	0.973	-2.402	3.454
6-7 years old	0.045	0.975	-4.794	3.377
8-9 years old	0.083	0.990	-4.643	3.703
Socio-emotional skills				
4-5 years old	0.079	0.961	-3.476	1.732
6-7 years old	0.085	0.909	-3.716	1.516
8-9 years old	0.101	0.909	-4.038	1.384
Physical health				
4-5 years old	0.084	0.908	-3.657	1.558
6-7 years old	0.042	0.977	-4.678	1.220
8-9 years old	0.063	0.969	-4.393	1.167
	Raw Variable			
	Mean	SD	Min	Max
Cognitive skills				
4-5 years old	65.632	5.450	51.978	84.782
6-7 years old	74.829	4.901	50.503	91.575
8-9 years old	79.557	4.766	56.804	96.983
Socio-emotional skills				
4-5 years old	8.253	4.795	0	26.000
6-7 years old	6.835	4.345	0	25.000
8-9 years old	6.392	4.524	0	27.000
Physical health				
4-5 years old	83.854	9.951	42.857	100.000
6-7 years old	83.773	13.459	18.750	100.000
8-9 years old	85.104	13.066	25.000	100.000

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 higher for children with a better socio-emotional skills.

Table 4: Descriptive statistics of control variables

Variable	Mean	SD
Time varying variables		
Pupil-teacher ratio	20.848	6.849
Teacher's years of experience	16.264	11.045
Equivalised household income	40,785.100	26,605.940
Family shocks		
Sickness of a close relative (dummy)	0.058	0.233
Sickness of a close friend (dummy)	0.100	0.300
Death of a close relative (dummy)	0.037	0.190
Death of a close friend (dummy)	0.184	0.387
Hours of informal care (deviation from the mean)	-0.152	2.788
Hours of formal care (deviation from the mean)	-0.164	2.562
Mainly using informal care (dummy)	0.187	0.390
Mainly using formal care (dummy)	0.153	0.360
Time invariant variables		
Intensive care at birth (dummy)	0.138	0.345
Male (dummy)	0.496	0.500
No. of children in the household	2.485	0.877
Mother with degree (dummy)	0.416	0.493
Unemployed or inactive mother (dummy)	0.198	0.398

Statistics of 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 2. Statistics of time variant variables are obtained pooling observations when children are 6-7 and 8-9 years old.

Table 5: Mothers' time investment by education and working status

	mothers without university degree	mothers with university degree	mothers with and without university degree
working mothers	729.370 (681.482)	740.862 (572.685)	734.486 (634.956)
non-working mothers	755.476 (682.885)	923.056 (640.702)	805.750 (673.146)
total	735.565 (681.261)	766.821 (585.439)	748.582 (642.938)

Notes. *** p <0.01, ** p <0.05, * p <0.1. Working status, educational level and time spent with the child measured when children are 8-9 years old. Mean time investment in minutes. Standard errors in parentheses.

Table 6: Mother's time investment model: main results

	Child fixed effects models	
	without IV	with IV
Cognitive skill	-17.049	52.778
	(25.317)	(47.122)
Socio-emotional skill	-88.510***	-116.647*
	(31.426)	(61.443)
Physical health	-0.923	-70.884
	(27.284)	(57.382)
Pupil-teacher ratio	20.866	10.704
	(15.861)	(16.239)
Pupil-teacher ratio (squared)	-0.672	-0.392
	(0.424)	(0.436)
Teacher experience (years)	0.227	1.025
	(1.902)	(1.925)
Household income	-0.002	-0.002
	(0.001)	(0.001)
Hours of informal care	-0.562	-10.827
	(15.126)	(15.477)
Hours of formal care	-32.179**	-29.227*
	(15.688)	(15.671)
Mainly using informal care	-5.910	58.238
	(84.763)	(87.070)
Mainly using formal care	103.140	72.805
	(104.004)	(104.333)
Constant	767.527***	-92.522***
	(158.065)	(28.309)
No. observations	1,820	1,820
No. children	910	910
F tests (first stages)		
Cognitive skill	-	122.51 [0.000]
Socio-emotional skill	-	102.02 [0.000]
Physical health	-	85.72 [0.000]
Endogeneity test	-	5.96 [0.1136]

Notes. *** p <0.01, ** p <0.05, * p <0.1. Standard errors are reported in parenthesis. *P – values* are reported in square brackets. In column 2 twice-lagged skills are used as instruments (IV).

Table 7: First stage regressions for the mother's time investment model

	First stage regressions		
	Dependent variable: first difference of		
	Cognitive skill	Socio-emotional skill	Physical health
Δ Pupil-teacher ratio	-0.028	-0.000	0.014
	(0.018)	(0.015)	(0.018)
Δ Pupil-teacher ratio (squared)	0.001*	0.000	-0.000
	(0.000)	(0.000)	(0.000)
Δ Teacher experience (years)	-0.002	0.001	0.003
	(0.002)	(0.002)	(0.002)
Δ Household income	1.03e-06	0.000	-0.000
	(1.62e-06)	(0.000)	(0.000)
Δ Hours of informal care	0.010	-0.010	0.012
	(0.017)	(0.014)	(0.017)
Δ Hours of formal care	0.017	0.004	-0.008
	(0.018)	(0.015)	(0.017)
Δ Mainly using informal care	0.081	-0.003	-0.083
	(0.097)	(0.081)	(0.095)
Δ Mainly using formal care	-0.011	0.072	0.012
	(0.116)	(0.097)	(0.114)
Double lagged cognitive skill	-0.584***	0.042*	0.052*
	(0.031)	(0.026)	(0.030)
Double lagged socio-emotional skill	0.038	-0.460***	0.075**
	(0.032)	(0.027)	(0.031)
Double lagged physical health	-0.035	0.052*	-0.518***
	(0.034)	(0.028)	(0.033)
Constant	0.009	0.036	0.009
	(0.032)	(0.026)	(0.031)
No. observations	1,820	1,820	1,820
No. children	910	910	910

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

Table 8: Mother's time investment model by educational level

	Child fixed effects models	
	without IV	with IVs
Mothers without a degree		
Cognitive skill	52.890	61.218
	(32.198)	(58.249)
Socio-emotional skill	-93.007**	-148.554*
	(39.298)	(75.889)
Physical health	13.266	-89.991
	(34.057)	(72.546)
Mothers with a degree		
Cognitive skill	-127.220***	37.442
	(40.527)	(79.935)
Socio-emotional skill	-74.999	-54.088
	(51.972)	(106.390)
Physical health	-19.544	-40.213
	(45.410)	(94.761)
Constant	802.786***	-90.452***
	(158.645)	(28.818)
No. observations	1,820	1,820
No. children	910	910
F tests (first stages)		
Cognitive skill	-	61.52 [0.000]
Socio-emotional skill	-	50.94 [0.000]
Physical health	-	42.97 [0.000]
Cognitive skill (interaction)	-	52.20 [0.000]
Socio-emotional skill (interaction)	-	44.97 [0.000]
Physical health (interaction)	-	42.72 [0.000]
Endogeneity test	-	9.192 [0.1631]

Notes. *** p <0.01, ** p <0.05, * p <0.1. Standard errors are reported in parenthesis. $P-values$ are reported in square brackets. In the estimation with IV we use twice-lagged skills as instruments. All models include the full set of covariates: pupil-teacher ratio, teacher's years of experience, household income and childcare measures.

Table 9: Mother's time investment model by employment status

	Child fixed effects models	
	without IV	with IVs
Mothers with a job		
Cognitive skill	-7.641	60.047
	(28.942)	(53.722)
Socio-emotional skill	-64.907*	-72.483
	(35.981)	(71.428)
Physical health	7.694	-73.183
	(30.915)	(64.950)
Mothers without a job		
Cognitive skill	-42.037	19.866
	(52.451)	(102.305)
Socio-emotional skill	-165.180**	-250.884**
	(64.630)	(119.808)
Physical health	-31.821	-75.376
	(58.251)	(122.394)
Constant	757.416***	-89.150***
	(158.222)	(28.529)
No. observations	1,820	1,820
No. children	910	910
F tests (first stages)		
Cognitive skill	-	61.42 [0.000]
Socio-emotional skill	-	51.35 [0.000]
Physical health	-	42.75 [0.000]
Cognitive skill (interaction)	-	54.70 [0.000]
Socio-emotional skill (interaction)	-	61.57 [0.000]
Physical health (interaction)	-	43.06 [0.000]
Endogeneity test	-	7.10 [0.3120]

Notes. *** p <0.01, ** p <0.05, * p <0.1. Standard errors are reported in parenthesis. $P-values$ are reported in square brackets. In the estimation with IV we use twice-lagged skills as instruments. All models include the full set of covariates: pupil-teacher ratio, teacher's years of experience, household income and childcare measures.

Table 10: Mother's time investment model by child's gender

	Child fixed effects			
	without IVs (baseline)	with IVs (baseline)	without IVs (interactions)	with IVs (interactions)
Baseline / Sons				
Cognitive skill	-17.049	52.778	-48.121	54.202
	(25.317)	(47.122)	(36.000)	(71.976)
Socio-emotional skill	-88.510***	-116.647*	-91.868**	-134.602*
	(31.426)	(61.443)	(41.836)	(81.364)
Physical health	-0.923	-70.884	21.235	-15.731
	(27.284)	(57.382)	(40.537)	(83.885)
Daughters				
Cognitive skill	-	-	15.507	51.626
			(35.804)	(66.949)
Socio-emotional skill	-	-	-80.760*	-103.913
			(48.104)	(98.414)
Physical health	-	-	-21.311	-121.682
			(36.849)	(76.953)
Constant	767.527***	-92.522***	761.643***	-94.409***
	(158.065)	(28.309)	(158.504)	(29.442)
No. observations	1,820	1,820	1,820	1,820
No. children	910	910	910	910
F tests (first stages)				
Cognitive skill	-	122.51 [0.000]	-	62.20 [0.000]
Socio-emotional skill	-	102.02 [0.000]	-	52.60 [0.000]
Physical health	-	85.72 [0.000]	-	43.25 [0.000]
Cognitive skill (interaction)	-	-	-	69.96 [0.000]
Socio-emotional skill (interaction)	-	-	-	52.17 [0.000]
Physical health (interaction)	-	-	-	44.55 [0.000]
Endogeneity test	-	5.96 [0.1136]	-	6.23 [0.398]

Notes. *** p <0.01, ** p <0.05, * p <0.1. Standard errors are reported in parenthesis. $P-values$ are reported in square brackets. In the estimation with IV we use twice-lagged skills as instruments. All models include the full set of covariates: pupil-teacher ratio, teacher's years of experience, household income and childcare measures.

Table 11: Father's time investment model by child's gender

	Child fixed effects			
	without IVs (baseline)	with IVs (baseline)	without IVs (interactions)	with IVs (interactions)
Baseline / Sons				
Cognitive skill	-6.946	0.592	-9.967	-27.860
	(12.977)	(24.405)	(18.471)	(37.421)
Socio-emotional skill	12.381	-66.310**	7.563	-84.560**
	(16.108)	(31.822)	(21.466)	(42.303)
Physical health	-9.882	9.488	-16.672	32.402
	(13.985)	(29.719)	(20.799)	(43.613)
Daughters				
Cognitive skill	-	-	-3.669	29.696
			(18.371)	(34.808)
Socio-emotional skill	-	-	20.316	-36.258
			(24.682)	(51.167)
Physical health	-	-	-4.323	-14.698
			(18.907)	(40.009)
Constant	239.712***	1.147	238.113***	4.849
	(81.021)	(14.661)	(81.328)	(15.307)
No. observations	1,820	1,820	1,820	1,820
No. children	910	910	910	910
F tests (first stages)				
Cognitive skill	-	122.51 [0.000]	-	62.20 [0.000]
Socio-emotional skill	-	102.02 [0.000]	-	52.60 [0.000]
Physical health	-	85.72 [0.000]	-	43.25 [0.000]
Cognitive skill (interaction)	-	-	-	69.96 [0.000]
Socio-emotional skill (interaction)	-	-	-	52.17 [0.000]
Physical health (interaction)	-	-	-	44.55 [0.000]
Endogeneity test	-	9.54 [0.023]	-	15.35 [0.018]

Notes. *** p <0.01, ** p <0.05, * p <0.1. Standard errors are reported in parenthesis. $P-values$ are reported in square brackets. In the estimation with IV we use twice-lagged skills as instruments. All models include the full set of covariates: pupil-teacher ratio, teacher's years of experience, household income and childcare measures.

Table 12: Mother's time investment model with family shocks covariates

	Child fixed effects models with	
	without IV	with IV
Cognitive skill	-16.766	54.533
	(25.376)	(47.085)
Socio-emotional skill	-87.616***	-118.196*
	(31.559)	(61.618)
Physical health	-0.109	-70.861
	(27.380)	(57.533)
Pupil-teacher ratio	20.777	10.841
	(15.902)	(16.272)
Pupil-teacher ratio (squared)	-0.671	-0.398
	(0.425)	(0.437)
Teacher experience (years)	0.179	1.010
	(1.908)	(1.932)
Household income	-0.002	-0.002
	(0.001)	(0.001)
Hours of informal care	-0.108	-10.156
	(15.183)	(15.521)
Hours of formal care	-31.133**	-28.457*
	(15.750)	(15.706)
Mainly using informal care	-2.830	58.003
	(85.077)	(87.270)
Mainly using formal care	102.972	72.958
	(104.178)	(104.358)
Family shocks		
Sickness of a close relative	7.583	-2.553
	(89.414)	(90.295)
Sickness of a close friend	84.043	59.031
	(66.849)	(67.025)
Death of a close relative	47.357	23.325
	(100.051)	(99.821)
Death of a close friend	9.503	15.915
	(48.959)	(49.190)
Constant	756.055***	-89.834***
	(158.608)	(28.546)
No. observations	1,820	1,820
No. children	910	910
F tests (first stages)		
Cognitive skill	-	122.88 [0.000]
Socio-emotional skill	-	101.74 [0.000]
Physical health	-	85.50 [0.000]
Endogeneity test	-	6.275 [0.099]

Notes. *** p <0.01, ** p <0.05, * p <0.1. Standard errors are reported in parenthesis. $P-values$ are reported in square brackets. In the estimation with IV we use twice-lagged skills as instruments.

Table 13: Mother's time investment model by number of children in the household level

	Child fixed effects models	
	without IV	with IVs
Only-child households		
Cognitive skill	62.621	123.842
	(83.563)	(131.034)
Socio-emotional skill	-190.790**	-307.263**
	(96.564)	(145.157)
Physical health	119.486	75.803
	(88.360)	(150.863)
Multiple-child households		
Cognitive skill	-21.494	43.549
	(26.416)	(49.396)
Socio-emotional skill	-80.195**	-88.537
	(32.873)	(65.191)
Physical health	-11.786	-87.095
	(28.242)	(58.910)
Constant	957.341***	-90.430***
	(268.122)	(28.481)
No. observations	1,820	1,820
No. children	910	910
F tests (first stages)		
Cognitive skill	-	61.17 [0.000]
Socio-emotional skill	-	52.21 [0.000]
Physical health	-	43.03 [0.000]
Cognitive skill (interaction)	-	59.94 [0.000]
Socio-emotional skill (interaction)	-	49.20 [0.000]
Physical health (interaction)	-	44.77 [0.000]
Endogeneity test	-	7.09 [0.3131]

Notes. *** p <0.01, ** p <0.05, * p <0.1. Standard errors are reported in parenthesis. $P-values$ are reported in square brackets. In the estimation with IV we use twice-lagged skills as instruments. All models include the full set of covariates: pupil-teacher ratio, teacher's years of experience, household income and childcare measures.

Table 14: Mother's time investment model using ordinary days

	Child fixed effects models	
	without IV	with IVs
Cognitive skill	20.434	-57.212
	(52.100)	(94.793)
Socio-emotional skill	-139.193**	-113.450
	(61.642)	(104.553)
Physical health	-97.659*	-103.827
	(56.288)	(92.869)
Constant	517.279*	-168.810***
	(302.918)	(55.301)
No. observations	316	316
No. children	158	158
F tests (first stages)		
Cognitive skill	-	24.74 [0.000]
Socio-emotional skill	-	24.84 [0.000]
Physical health	-	30.34 [0.000]
Endogeneity test	-	1.05 [0.7899]

Notes. *** p <0.01, ** p <0.05, * p <0.1. Standard errors are reported in parenthesis. $P-values$ are reported in square brackets. In the estimation with IV we use twice-lagged skills as instruments. All models include the full set of covariates: pupil-teacher ratio, teacher's years of experience, household income and childcare measures.

Table 15: Mother's time investment model: logarithm of time

	Child fixed effects models with	
	without IVs	with IVs
Cognitive skill	-0.066	0.075
	(0.077)	(0.143)
Socio-emotional skill	-0.224**	-0.210
	(0.096)	(0.186)
Physical health	0.105	-0.033
	(0.083)	(0.174)
Pupil-teacher ratio	0.042	-0.000
	(0.048)	(0.049)
Pupil-teacher ratio (squared)	-0.002	-0.000
	(0.001)	(0.001)
Teacher experience (years)	0.000	0.002
	(0.006)	(0.006)
Household income	-0.000	-0.000
	(0.000)	(0.000)
Hours of informal care	-0.006	-0.046
	(0.046)	(0.047)
Hours of formal care	-0.003	0.007
	(0.048)	(0.047)
Mainly using informal care	-0.187	0.068
	(0.259)	(0.264)
Mainly using formal care	-0.457	-0.573*
	(0.318)	(0.316)
Constant	6.180***	-0.360***
	(0.483)	(0.086)
No. observations	1,820	1,820
No. children	910	910
F tests (first stages)		
Cognitive skill	-	122.51 [0.000]
Socio-emotional skill	-	102.02 [0.000]
Physical health	-	85.72 [0.000]
Endogeneity test	-	2.38 [0.497]

Notes. *** p <0.01, ** p <0.05, * p <0.1. Standard errors are reported in parenthesis. *P – values* are reported in square brackets. In column 2 twice-lagged skills are used as instruments (IV).

Table 16: Mother's time investment model: Estimation using additional instruments

	Child fixed effects models	
	with IVs	with IVs
	exactly identified	over-identified
Cognitive skill	52.778	54.251
	(47.122)	(47.029)
Socio-emotional skill	-116.647*	-119.846*
	(61.443)	(61.161)
Physical health	-70.884	-62.717
	(57.382)	(56.995)
Pupil-teacher ratio	10.704	10.601
	(16.239)	(16.230)
Pupil-teacher ratio (squared)	-0.392	-0.389
	(0.436)	(0.436)
Teacher experience (years)	1.025	0.995
	(1.925)	(1.924)
Household income	-0.002	-0.002
	(0.001)	(0.001)
Hours of informal care	-10.827	-11.068
	(15.477)	(15.467)
Hours of formal care	-29.227*	-29.347*
	(15.671)	(15.662)
Mainly using informal care	58.238	58.943
	(87.070)	(87.022)
Mainly using formal care	72.805	74.106
	(104.333)	(104.270)
Constant	-92.522***	-92.272***
	(28.309)	(28.293)
No. observations	1,820	1,820
No. children	910	910
F tests (first stages)		
Cognitive skill	122.51 [0.000]	61.27 [0.000]
Socio-emotional skill	102.02 [0.000]	51.42 [0.000]
Physical health	85.72 [0.000]	43.40 [0.000]
Endogeneity test	5.96 [0.1136]	5.71 [0.1267]
Sargan test	-	1.65 [0.6476]

Notes. *** p <0.01, ** p <0.05, * p <0.1. Standard errors are reported in parenthesis. $P-values$ are reported in square brackets. Column 1 shows results from the exactly identified model, where twice-lagged skills. Column 2 provides results from the overidentified model, where twice-lagged skills as well as their interactions with a dummy for child's neonatal intensive care are used as instruments.

Appendix A

Table 1: List of developmental activities included in the parental time investment measure

Activity Category	**List of Activities**
Eating	eating, drinking
Personal Care	bathing, dressing, hair care, health care
Educational Activities	read a story, talked/sung to, sing/talk, helping with chores, job
Leisure Activities	organised sport or physical activity (e.g.swim/dance), other organised lesson or activity (e.g.music, drama), active free play (e.g. running, climbing, ball game), quiet free play (e.g. craft, dress-ups), taken places with adult (e.g.shopping), visiting people or special event, walking (for travel or fun), ride bicycle or trike (for travel or fun)
Psychological Support	held, cuddled, hugged, comforted, soothed

In the LSAC, time-use diares allow to record contemporaneous activities in each time interval, implying that the sum of child's time could exceed 24 hours in a day. Differently than other datasets that comprise time use diaries (as the Child Development Supplement from the Panel Study of Income Dynamics), the LSAC does not distinguish among primary and secondary activities. Therefore we have defined an algorithm in order to define the main (or primary) activity when two or more activities are recorded:

1. Educational Activities
2. Psychological Support
3. Leisure Activities
4. Eating
5. Personal Care

Appendix B

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 items presented in picture plates, arranged in a multiple-choice format. Children are asked to "select the picture that best illustrates the meaning of the stimulus word presented orally by the examiner" (Dunn and Dunn 1997).

The **Strength and Difficulty Questionnaire (SDQ)** is a behavioural screening questionnaire composed by 25 items divided in 5 subscales (peer problems, emotional symptoms, hyperactivity, conduct problems and prosocial behaviour) . The parent, who was the main carer, reports whether the description was certainly true, "somewhat true" or "not true". Each item scores from 0 (non true) to 2 (certainly true). Higher scores indicate more negative symptoms, except for the scores indicating prosocial behaviour. Here below we report the questions asked in the SDQ.

- *SDQ Peer problems subscale*: mean of 5 parent-rated items assessing problems in the child's ability to form positive relationships with other children
  - rather solitary, tends to play alone
  - does not havehas at least a good friend
  - generally not liked by other children
  - picked on or bullied y other children
  - gets on better with adults than with other children
- *SDQ Emotional symptoms subscale* : mean of 5 parent-rated assessing a child's frequency of display of negative emotional states :
  - 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*: mean of 5 parent-rated items assessing child's fidgetiness, concentration span and impulsiveness:

  - restless, overactive, cannot stay still for long
  - constantly fidgeting or squirming
  - easily distracted, concentration wanders
  - does not stop and thinks things out before acting
  - doesn not sees tasks through to the end, poor attention span

- S*DQ Conduct subscale*: mean of 5 parent-rated items assessing child's tendency to display problem behaviours when interacting with others:
  - often has temper tantrums or hot tempers
  - not generally obedient, usually does not what adult requests
  - often fights with other children or bullies them
  - often argumentative with adults
  - can be spiteful with others

- *SDQ Prosocial subscale:* mean of 5 parent-rated items assessing the child's propensity to behave in a way that is considerate helpful to others:
  - 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 Paediatric 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 item 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.