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Do parental time investments react to changes in child's skills and health?

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ABSTRACT

Parental time investment decisions have been found to have important effects on child development; however, little is known about the response of parents to changes in their child's human capital across time. Using the Longitudinal Study of Australian Children, we measure time investments considering the time young children spend, with or without parents, in different activities. By adopting a child fixed-effect instrumental variable estimation, we find that parents reinforce for high socio-emotional skills by spending more time socialising with their child and compensate for low cognitive skills by increasing the time the child spends in learning activities.

1. Introduction

Parental time investments have been found to play a crucial role in fostering child development (Hsin, 2007; Del Boca et al., 2014; Fiorini and Keane, 2014; Attanasio et al., 2015; Carneiro et al., 2015; Del Bono et al., 2016; Deckers et al., 2017 and Doepke et al., 2019). However, no studies to date have empirically investigated how parents adjust their time investments to changes in their child's human capital throughout childhood. There is only indirect evidence on the response of parental time investments drawn from the estimation of production models for child's skills, rather than directly from parental time investment models. In particular, Attanasio et al. (2015) and Del Bono et al. (2016) find that the productivity of parental time investments for child's socio-emotional and cognitive skills is larger when correcting for the endogeneity of parental time investments and interpret this as evidence of parents compensating for negative shocks to their child's skills. While interesting, this evidence provides information only on the direction of the parental investment response and does not comment on its magnitude.

This paper provides the first direct empirical evidence of both the direction and the magnitude of the parental time investment response to changes in child's human capital during middle childhood, defined as the period between ages 6

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and 9. An understanding of the response of parental investments to changes in their child's human capital in this period of life is of compelling interest as in middle childhood, cognitive and socio-emotional skills as well as physical attributes are not yet stabilised and are sensitive to investments (see, e.g., Cunha and Heckman, 2007; Del Giudice, 2018). Additionally, in an unequal society, where disadvantaged children are more likely to experience adverse shocks, parental time investments can play a crucial role. Negative effects of adverse shocks affecting child's human capital could be attenuated if parents compensate. On the contrary, the effect of adverse shocks could be exacerbated by a reinforcing parental investment strategy, contributing to the intergenerational transmission of inequality.

Using the Longitudinal Study of Australian Children (LSAC), we account for the multidimensionality of child human capital by considering three measures: health, cognitive and socio-emotional skills. We employ time-use diaries to measure time investments. Most of the previous papers define parental time investments as the time spent by a child together with parents in activities such as learning and playing.[1] As shown by Del Boca et al. (2014) and Del Boca et al. (2017), the productivity of such time investments reduces with child's age and, therefore, the time spent with parents is likely to be more important for child development in early than in middle childhood.

When children get older what becomes more relevant is the time they spend in formative activities, which include activities done on their own, with their peers or with adults, who are not necessarily their parents. The increasing importance of formative activities does not mean that parental time investment decisions become irrelevant when moving from early to middle childhood. Parents still have an important role in taking decisions about the time allocation of children to different activities. As emphasised by Kalil et al. (2012), while child development in the preschool years can be fostered by the time parents spend with their child, what matters more in middle childhood is the parental managing and monitoring of the child's time. Ultimately, both the time parents spend with their children and the total time children spend in different activities, regardless of the presence of their parents, are the result of parental decisions on the time allocation of the child. For this reason, in the paper we consider both the time parents spend with children as well as children's total time allocation to different types of activities.

Similar to Fiorini and Keane (2014), we differentiate the time the child spends in various types of activities so that we can assess which type of time input is more reactive to each of the three measures of child's human capital. In particular, we distinguish between time spent in school, in other learning activities (e.g., reading and private lessons), socialising (e.g., visiting people), exercising (e.g., walking and sport activities), quietly playing, using media (e.g., watching television, listening the radio, using a PC), in basic care (e.g., eating and personal care), sleeping, and in other activities. Time allocation to various activities differ from most of the other measures of investments considered in the child development literature by being more flexible and adjustable in the short term. Indeed, it is easier for parents to reallocate the time a child spends in different activities then to change other inputs, such as parents' labour supply or school quality.[2]

Economic models capturing how parental investment decisions react to changes in the child's human capital are complex and depend on the interaction of several factors, such as (i) the cost of investments and parental resources; (ii) the productivity of the investment or parents' belief on this productivity;[3] (iii) parental preferences for child quality; (iv) allocation of resources among several children;[4] and (v) interdependencies of the parental investments with other parental decisions (see Bernal, 2008, Del Boca et al., 2014 and Brilli, 2017). Without imposing restrictive assumptions on all the above factors, the sign of the effect of child's human capital on parental investments is ambiguous and ultimately a question to be investigated empirically.

While there are no studies analysing the response of parental time investments to changes in child's human capital during childhood, Hsin (2012) uses time-use diaries to evaluate the reaction of maternal time investments to child's birth weight. As in most previous studies examining the response of parental investments to child's endowment at birth, Hsin (2012) identifies the parental response by considering sibling differences in birth weight and in parental investments. Hsin (2012) assumes that such differences are uncorrelated with differences between siblings in unobserved variables.[5] However, there are several cases where this assumption does not hold. For example, if parents tend to invest more in one of the two siblings both during pregnancy and after birth, then neglecting to control for differences between siblings in prenatal investments will lead to an endogeneity bias.

Adopting a sibling difference estimation when considering the response of parental time investments to changes in child's human capital during childhood could lead to an even more serious endogeneity issue. Sibling differences in human capital observed in middle childhood depend on sibling differences in both pre- and post-birth investments and this makes more difficult to control for all variables that can cause an endogeneity bias. For this reason, we identify the response of

[1] See, for example, Stafford and Yeung (2004); Hsin (2007); Price (2008); Hsin (2009); Carneiro and Rodrigues (2009); Del Boca et al. (2014); and Del Boca et al. (2017).

[2] Using the LSAC, we find empirical evidence that other types of investment, such as mothers' worked hours, do not respond to changes in the child's human capital across time. On the contrary, time inputs such as learning time and socialising time with parents respond to changes in child human capital.

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

[4] Se, for instance, the economic models considered by Behrman et al., 1982; Becker and Tomes, 1986; Caucutt and Lochner, 2012; Del Boca et al., 2014.

[5] While Hsin (2012) is the only paper that analyses the parental response to the child's endowment at birth in terms of parental time investments, other papers examine different types of parental investments such as Restrepo (2016), who considers the Home Observation for Measurement of the Environment (HOME), and Grätz and Torche (2016), who examine the differential response of parental involvement to differences in birth weight between twins. For a review of this literature see Currie and Almond (2011), Almond and Mazumder (2013) and Nicoletti and Tonei (2017).

parental investments using a panel data approach, that is, looking at how parents change their time investments between ages 6–7 and 8–9 in reaction to changes in the child's skills. This is equivalent to adopting a child fixed-effect estimation which accounts for all child's specific characteristics and parental investments that are invariant between ages 6–7 and 8–9. To account for the potential residual endogeneity in the child's human capital caused by time-varying unobservables and reverse causality, we adopt an instrumental variable estimation which uses past measures of the child's human capital as instruments. Ultimately, our estimation strategy consists of an instrumental variable estimation with child fixed-effects, which does not restrict the focus exclusively on parents with at least two children, as required by the estimations based on sibling differences.

Our results show that while non-discretionary time inputs, such as school and sleeping time, do not vary when the child's human capital changes, other types of time inputs do. We find that the time children spend in learning activities (out of school), using media as well as the time parents spend with their children socialising react to changes in the child's human capital. Whereas previous studies find mixed results on the effects of media use on child's skills (see Schmidt and Vandewater 2008, Fiorini 2010), there is a clear evidence that the time children spend learning can have a positive effect on their cognitive skills (Kalil et al. 2012) and that the time children spend in social activities with their parents can positively affect their socio-emotional skills (see Sokol et al., 2010 for a discussion on how social interactions can have an effect on child self-regulation and executive development). Given this evidence, we have decided to provide a more detailed analysis only for learning and socialising time, i.e. activities that are productive for the human capital of the child.

We find that for one standard deviation decrease in child's cognitive skills, parents seem to compensate by raising the time the child spends in learning activities by about 40 minutes per week. On the contrary, when a child experiences one standard deviation decrease in her socio-emotional skills, parents adopt a reinforcing strategy by reducing the time spent socialising with the child by 4 hours per week.

Exploring the heterogeneity of parental response by parental characteristics, we provide insights on the role of some parents-specific factors (e.g., parents' time constraints, beliefs and preferences) in explaining parental investment decisions. For example, we find that non-working mothers compensate more than working mothers for low cognitive skills by increasing the time the child spends learning. In contrast, working mothers reinforce more than non-working mothers by increasing the time spent socialising with the child in case of an improvement in the child's socio-emotional skills. This seems to suggest that the time opportunity cost is lower for non-working mothers and that the psychic cost of socialising with a child with low socio-emotional skills, is higher for working mothers, who are potentially more psychologically strained than non-working mothers. This interpretation is justified by the empirical evidence showing that parents' response to their child socio-emotional skills is driven by the child's externalising behavioural issues such as misconduct and hyperactivity problems.

Given that we are concerned about potential differences between subjective measures of human capital reported by parents and the corresponding objective measures, we also assess how results change when considering objective rather than subjective measures.[6] Results are encouraging as they suggest that the potential bias caused by the parental misperception of changes in child's socio-emotional skills is negligible.

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

The remainder of the paper is organized as follows. Section 2 presents the conceptual framework and estimation strategy of the parental time investment model. We describe the sample and variables in Section 3, while we report our main results in Section 4. Section 5 provides empirical evidence on the validity of our child fixed-effect instrumental variable estimation and model specification. Finally, Section 6 concludes.

2. The parental time investment model

In this section we provide some insights on how our empirical analysis relates to the standard economic literature on parental investment models (see, e.g., Behrman et al., 1982; Becker and Tomes, 1986). As shown below, our approach consists of approximating the parental time investment decision model with a policy function, rather than estimating a full dynamic structural model. Such structural model would require strong assumptions on parental preferences, parental beliefs on child's human capital as well as the production function of child's health, cognitive and socio-emotional skills. In this way, we allow our analysis to accommodate different theoretical models of parental time investments and we assess empirically whether these investments are compensating, neutral or reinforcing for changes in child' skills and health.

2.1. The conceptual framework

In the economics literature, it is common practice to assume that parents maximise a utility function that depends on parental consumption, their child's human capital or future wages, income or wealth (Behrman et al.,

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

1982; Becker and Tomes, 1986). We assume that parents make decisions in each child's life stage of development, denoted with the subscript t, and that there are T sequential stages between birth and adulthood, $t = 1, \dots, T$ (Del Boca et al., 2014). 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 row 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 child's. 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 maximise 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:

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

where $\theta_{i,t}^k$ 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.[7] 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 there is no saving or borrowing so that parental decisions are resource-constrained at each stage t by

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

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

We do not impose any additional assumption on the utility function (1) and on the human capital production model (2) except strict concavity and twice continuously differentiability to ensure 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 with the following policy function:

$$I_{i,t}^{Time} = f_t(\boldsymbol{\theta}_{i,t-1}, \boldsymbol{\theta}_i^P, Y_{i,t}, I_{i,t}^{Care}, I_{i,t}^{School}, \mathbf{p}_t, \boldsymbol{\upsilon}_i, \mu_i, \boldsymbol{\eta}_{i,t}, u_{i,t}), \tag{4}$$

where $\mathbf{p}_t = [p_t^{Time}, p_t^{Care}, p_t^{School}]$, $\boldsymbol{\upsilon}_i = [\upsilon_i^H, \upsilon_i^C, \upsilon_i^S,]$, $\boldsymbol{\eta}_{i,t} = [\eta_{i,t}^H, \eta_{i,t}^C, \eta_{i,t}^S]$, $u_{i,t}$ 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 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.

A positive (negative) value of $\partial I_{i,t}^{Time} / \partial \theta_{i,t-1}^k$ would imply that parental investments are reinforcing (compensating) in ability of type k. We use the terms reinforcing and compensating because we are assuming that $I_{i,t}^{Time}$ is productive for child's human capital of type k. In the empirical section, we consider a full set of different types of time investments. Not all of these time investments are necessarily productive, so we use the terms reinforcing and compensating only for investments that can be reasonably assumed to be productive, while we will speak simply of positive and negative parental response for investments for which we are unsure about the sign of the effect on child's skills.

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. 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, then there is complementarity between the parental investment in stage t and endowment in stage $(t-1)$, which can justify a reinforcing investment strategy.

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

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

The theoretical framework we describe above is quite flexible and can be extended to consider simultaneous decisions that parents take in terms of time investments, childcare and labour supply (see Bernal, 2008; Del Boca et al., 2014 and Brilli, 2017). While we do not present such an extension of the framework, which would require deriving a full structural model and imposing several restrictive assumptions, we account for simultaneous decisions in our empirical model (see Section 2.2 and 4 for more details).

Some previous papers imposed restrictive assumptions on a full structural model to explicitly derive an investment model. For example Behrman et al. (1982) impose a CES (constant elasticity of substitution) parental utility function and demonstrate that parental investment decisions are uniquely determined by parameters associated to parental preferences.[8] In this paper we avoid imposing too restrictive assumptions on child's production function, parental preferences and beliefs by approximating the parental investment strategy using a policy function. The main disadvantage of our approach is that we cannot empirically identify the parameters of the full structural model. However, this is beyond the purpose of this paper.

2.2. 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 investments.

In the empirical analysis, we follow a cohort of Australian children from age 4–5 (stage 0). We observe parental time investments at ages 6–7 (stage 1) and 8–9 (stage 2) as well as child's human capital at ages 4–5 and 6–7 (stages 0 and 1). We adopt a set of different measures for parental time investments. More precisely, we consider both the time parents spend with their child in different activities and the total time a child spends in such activities regardless of the presence of parents.

By assuming that the investment model (4) is linear and additive in its inputs and that its parameters are invariant between stages 1 and 2 (invariance assumption), 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 and 0 for stage 1, 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}), $\boldsymbol{\theta}_{i,t-1} = [\theta_{i,t-1}^H, \theta_{i,t-1}^C, \theta_{i,t-1}^S]$ is the 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 ages 6–7 and 8–9 and consisting of a linear combination of μ_i and υ_i^k for $k = H, C, S$. $\epsilon_{i,t}$ is an idiosyncratic error 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.

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 into a potential correlation between $\theta_{i,1}^k$ and $\epsilon_{i,1}$ (the error term in Equation (5)) and, as a result, into a potential correlation between $\Delta\boldsymbol{\theta}_{i,1}$ and $\Delta\epsilon_{i,2}$ in Equation (6).

To correct for the consequent biases caused by these two sources of endogeneity we instrument $\Delta\boldsymbol{\theta}_{i,1}$ with $\boldsymbol{\theta}_{i,0}$. This approach is equivalent to the estimation used by Rosenzweig and Wolpin (1988) and Rosenzweig and Wolpin (1995) to solve the issue of endogeneity in a model for childbirth outcomes. The instruments $\boldsymbol{\theta}_{i,0} = [\theta_{i,0}^H, \theta_{i,0}^C, \theta_{i,0}^S]$ 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.[9] In Appendix C, we show that adopting this instrumental variable estimation with child fixed effect (FE-IV) is equivalent to adopting a Generalized Methods of Moments (GMM) estimation, as explained in Rosenzweig and Wolpin (1995) and Del Bono et al. (2012).

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

[8] See also Appendix B in Yi et al. (2015).

[9] For a more exhaustive discussion on the validity of our instruments, see Section 5.

follows

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

where $k = H, C$ and S; $\mathbf{X_{i,2}}$ is a row vector of all remaining control variables in (6), and $\nu_{i,\,1}$ 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 skill (or health) $\theta_{i,1}^{k}$ depends on its lagged value $\theta_{i,0}^{k}$ and also potentially on the lagged values of the other two measures of the child's human capital $\theta_{i,0}^{h}$ for $h \neq k$, implying that our instrumental variables are relevant. Because $\Delta\theta_{i,1}^{k} = \theta_{i,1}^{k} - \theta_{i,0}^{k}$, we expect the effect of the instrument $\theta_{i,0}^{k}$ in the first stage regression (7) to be negative.

The variation in our instruments $\theta_{i,0}^{C}$, $\theta_{i,0}^{S}$ and $\theta_{i,0}^{H}$ can be driven by investments and environmental conditions during pregnancy and in early life, such as health behaviours of the mother during pregnancy, breastfeeding, pre-school parental time investment, number of siblings, birth order and childcare arrangements. These prenatal and early life inputs can also have a direct effect on parental time investments in later stages, $I_{i,1}^{Time}$ and $I_{i,2}^{Time}$. For this reason, we allow these prenatal and early inputs to explain parental time investments in both stages 1 and 2, but we assume that their effect is the same for these two stages. This implies that any direct effect of observed and unobserved inputs during pregnancy and in early life is captured by the individual effect μ_i, which we control for by considering a child fixed-effect estimation. Assuming that the effects of prenatal and early inputs on $I_{i,1}^{Time}$ and $I_{i,2}^{Time}$ are the same is simply a consequence of the invariance assumption imposed by model (5). This invariance assumption is credible because parental investments behaviour is unlikely to have a structural change between stages 1 and 2 when children are enrolled in primary school and aged 6–7 and 8–9.

By adopting a child fixed-effect estimation, we also control for the potential endogeneity bias caused by the fact that parental time investments are determined simultaneously with other parental decisions. For example, if a child has a disability, this will influence parental time investments as well as labour supply of the mother, childcare and school choices. Child disability, as well as any other child-specific characteristic that do not change between stages 1 and 2, is captured by the individual component μ_i in our model. Our child fixed-effect estimation allows us to control for this individual component and it is equivalent to estimating a joint model for the different parental decisions which allows for correlation between individual error terms.

Nevertheless, if changes in child human capital between stages 0 and 1 lead to changes in school choice, childcare arrangements or mother's labour supply and these in turn affect parental time investments, then we could have an endogeneity issue if we do not control in the investment model for these other parental decisions. For this reason, we allow the parental time investment to depend on type of childcare arrangements and hours of childcare by adding them as explanatory variables. We do not find any statistically significant difference for the response of parental time investments to child's human capital when further controlling for these inputs (see Section 4), suggesting there is no endogeneity issue.

When we add the mother's working hours as additional covariate, we find that not only the response of parental time investment to child's human capital remains unaltered, but also the effect of mother's working hours is not statistically significantly different from zero. This is not surprising considering previous empirical papers show that (a) the time mothers spend with children doing formative activities is quite similar for working and non-working mothers (Nock and Kingston, 1988), and (b) increases in the mothers' number of hours at work do not translate into significant changes in their time investment (Bittman, 1999; Bianchi, 2000; Sandberg and Hofferth, 2001; Booth et al., 2002; Gauthier et al., 2004). Similarly, when we add school inputs as controls (proxied by the pupil-teacher ratio and two dummy variables for catholic and private schools, respectively) we do not find any statistically significant effect of these school characteristics. This result is indicative that there is little variation left between ages 6–7 and 8–9 in these school characteristics once controlled for the child fixed-effect.

The presence of other children in the household may bias our estimation because the time parents spend with a child may be affected by the human capital of her siblings. However, the child fixed-effect controls for unobserved siblings' human capital that does not vary between stage 0 and stage 1. We are therefore controlling for the possibility of having a sibling who is very gifted or, on the contrary, has cognitive, socio-emotional or health issues which are invariant between stage 0 and stage 1. Thus, the omission of the siblings' human capital causes a bias only if the following two conditions hold: (i) there is correlation between the human capital of a child at stage 0 (our instrumental variable) and changes in her siblings' human capital between her stage 1 and 2, conditional on the covariates; (ii) the difference in parental investments between stage 1 and 2 depends on the difference between stage 1 and 2 in the human capital of other siblings in the household. We think that these two conditions might hold only for extreme changes in the human capital of siblings, which are usually associated with rare events such as a severe illness. We do control for such types of health shocks of family members in a sensitivity analysis in Section 5, and we find that our main results do not change.

A final remark is needed to explain the consequences of potential zeros observed for the parental time investment measure on our econometric estimation. The presence of zeros is a common issue when measuring time spent in specific activities over a short period as in our case, where parental time investment is observed only for 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 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 the presence of zeros. This consistency result also applies 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.

3. Data

Our analysis relies on the first three waves of the Longitudinal Study of Australian Children (LSAC). Since 2004, LSAC has conducted a biannual survey collecting information on two nationally representative samples of Australian children.[10] The two samples of children are cohort B (baby), which follows 5107 children aged 0–1 in 2003–2004, and cohort K (kindergarten), which follows 4983 children aged between 4–5 in 2003–2004.

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

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

3.1. Sample selection

We restrict the LSAC original kindergarten sample to children for whom details on time investments are available both at ages 6–7 and 8–9.[11] Among them, we narrow the sample to children living in intact families, that is with both biological parents (1,753 children). Because our empirical results are based on child fixed-effect methods that require at least three observations for each child, we use a balanced panel sample of children who have been observed in all the first three waves, that is, when they are 4–5, 6–7 and 8–9 years old (1,645 children). Finally, we drop children with missing information in any of the explanatory variables used in our main analysis, which leaves us with a *main sample* of 1313 children.

In addition to the main sample, we also consider an *ordinary-day sample* that includes only children for whom the time-use diaries were filled in days that parents classify as ordinary, i.e. excluding unusual days such as holidays. When restricting the sample to children with time diaries filled in ordinary days in both waves, the sample size reduces to 835.

In our empirical application, we also run a set of sensitivity analyses where we consider alternative measures of child's human capital that are not observed for all 1313 children. In these specific sensitivities, the sample sizes decrease of a maximum of 20%.

3.2. 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 children spend in a variety of activities either alone or with other people, including their parents.[12] For each of the first three waves, the LSAC collects details on the activities done by the child on 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 activities done by the child (by choosing from a list of 26 pre-coded activities), where these activities 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 how we constructed our time-inputs measures using TUDs.

As explained in Section 1, we consider two types of parental time inputs: the total time children spend in different activities, regardless of who is with them, and the time that they spend doing such activities with their parents. We classify activities in 9 mutually exclusive groups that indicate the time a child spends (i) at school (*school time*); (ii) in other learning activities, e.g. reading (*learning time*); (iii) socialising (*socialising time*); (iv) doing physical activity, e.g. playing outdoor (*exercise time*); (v) quietly playing indoor (*play time*); (vi) using TV, radio, phones or other electronic devices (*media time*); (vii) in basic care, such as bathing (*care time*); (viii) napping or sleeping (*sleep time*) and (ix) in other activities, for instance, traveling (*other time*).[13] When focusing on the time spent with their parents (mother, father or both), however, we exclude school time, sleep time and other time since for these activities, the parents' presence is less relevant.

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

[11] For each wave and each child the time investment measures are derived by using details from two time-use diaries covering a weekend day and a working day. We exclude those cases where one of the time use diaries were not filled. We also exclude cases where, out of the 24 hours covered by each diary, we have more than two hours of missing information.

[12] Previous papers that have measured parental investments using time diaries include Stafford and Yeung (2004), Hsin (2007), Price (2008), Carneiro and Rodrigues (2009), Hsin (2009), Fiorini and Keane (2014), Del Boca et al. (2014), Del Boca et al. (2017).

[13] Further details on the definition of parental time investments are reported in Appendix A.

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

	Wave 2						Wave 3					
	Zeros	Mean	SD	Min	Max	Skewness	Zeros	Mean	SD	Min	Max	Skewness
Panel A: Children total time												
School time	289	1585.213	894.224	0	3600	-1.013	379	1457.228	977.254	0	3975	-0.669
Learning time	63	433.572	317.941	0	2625	1.814	83	470.529	388.051	0	3645	2.095
Socialising time	281	536.196	699.786	0	8370	3.840	287	581.653	749.628	0	8505	3.074
Exercise time	38	737.399	528.042	0	5775	1.991	44	768.233	631.837	0	4725	1.857
Play time	199	408.347	382.422	0	3540	1.779	260	388.081	422.345	0	3270	1.931
Media time	33	721.976	495.680	0	5295	1.792	17	890.552	587.372	0	4245	1.481
Basic care time	1	822.589	297.723	0	2895	0.912	1	789.208	308.156	0	2670	0.754
Sleep time	0	2272.555	646.038	360	6945	-2.087	0	4133.340	652.577	720	6015	-1.764
Other activities	101	421.234	490.129	0	3660	2.835	70	438.519	448.700	0	3780	3.012
Panel B: Children time with parents												
Learning time	124	326.790	264.550	0	2505	1.753	179	313.298	281.437	0	2175	1.524
Socialising time	371	398.397	521.923	0	6375	3.074	386	406.679	547.993	0	4995	2.742
Exercise time	127	488.682	437.432	0	5655	2.718	138	473.511	469.399	0	4245	2.265
Play time	368	245.518	286.202	0	2355	1.966	466	223.583	325.418	0	3270	2.975
Media time	128	473.957	424.370	0	4695	2.164	87	608.808	493.066	0	4095	1.702
Basic care time	21	649.353	302.454	0	2580	0.574	29	600.366	296.394	0	1860	0.460
Total parental time	15	2582.696	1021.44‘	0	8700	0.590	12	2626.245	1,097.828	0	7365	0.615
N. children			1,313						1,313			

We compute the total number of minutes a child spends in each of these groups of activities in the randomly assigned working day (working day time) and in the randomly assigned weekend day (weekend day time). We then define the weekly time investment in each specific activity as the working day time spent in the specific activity multiplied by five plus the corresponding weekend day time multiplied by two. Summary statistics for all the time investments, measured when children are 6–7 and 8–9, are reported in Table 1.

As expected, when children are 6–7 years old, the activities they spend more time on are sleeping (approximately 70 hours in week) followed by school time (26.4 hours in a week). They also spend about 433 minutes, which correspond to about one hour per day, in learning activities outside school. When focusing on the time with parents, we find that the most frequent type of activity is basic care (649 minutes in a week). Other activities parents do with their children include outdoor activities (489 minutes in a week), using media (474 minutes in a week) and socialising (398 minutes in a week). Interestingly, the time that children spend with their parents remains quite stable over the years, this being the case both for the total parental time (i.e. the time spent in all the activities, but school, sleeping, media and other time) as well as for most of the activities considered separately. The only exceptions are media time, which increases from 474 to 609 minutes in a week, and basic care time, which decreases from 649 to 600 minutes.

3.3. Child's skills and health

In our analysis, we follow the approach of Borghans et al. (2008), Cunha et al. (2010), and Almlund et al. (2011) and we allow for multiple dimensions of human capital. In particular, we focus on the child's cognitive and socio-emotional skills and physical health measured in each of the first three waves of the LSAC. We measure the child's cognitive skills using the Peabody Picture Vocabulary Test (PPVT - III), which has been administered to the LSAC children in a version adapted for Australia and based on work done in the United States for the Head Start Impact Study. This test is specifically designed to assess the child's verbal ability and scholastic aptitude and to capture real changes in the child's functioning rather than just changes in position relative to peers (Dunn and Dunn, 1997; Rothman, 2005).[14] 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.

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

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

	Standardised Variable			
	Mean	SD	Min	Max
Cognitive skills				
Age 4–5	0.044	0.983	-2.422	3.465
Age 6–7	0.044	0.973	-4.801	2.841
Socio-emotional skills				
Age 4–5	0.068	0.936	-4.981	1.513
Age 6–7	0.065	0.935	-4.045	1.375
Physical health				
Age 4–5	0.038	0.955	-4.673	1.218
Age 6–7	0.042	0.944	-5.181	1.159
	Raw Variable			
	Mean	SD	Min	Max
Cognitive skills				
Age 4–5	65.718	5.475	51.978	84.782
Age 6–7	74.902	4.899	50.503	88.983
Socio-emotional skills				
Age 4–5	6.897	4.468	0	31
Age 6–7	6.526	4.657	0	27
Physical health				
Age 4–5	83.729	13.166	18.750	100
Age 6–7	84.892	12.761	14.286	100

Notes. Standardised variables are obtained by re-scaling the raw scores to have mean zero and standard deviation 1. The raw socio-emotional variable measures child's behavioural problems, therefore a higher score implies more socio-emotional problems. On the contrary, the standardised socio-emotional variable is recoded and standardised to be higher for children with better socio-emotional skills.

The child's health is measured by the physical health sub-scale of the Pediatric Quality of Life Inventory (PEDS QL), which is composed of eight items measuring motor coordination and general health (see Varni et al., 1999). The composite score we use is scaled to range from 0 (poor) to 100 (good).[15]

We standardize each of the three above scores, separately by child's stage, to have a mean of 0 and standard deviation 1. In our empirical application we make sure to avoid the reverse causality issue by explaining time investments with lagged measures of the child human capital that are observed before the parental time investments. To explain time investments at ages 6–7 (8–9) we consider child's human capital measures before age 6–7 (8–9) interview. In particular, we use child cognitive skills at age 4–5 (6–7) interview, socio-emotional skills observed in the 6 months before age 6–7 (8–9) interview and physical health observed in the month before ages 6–7 (8–9) interview. To simplify the exposition, we refer in the following way to human capital measures "before age 6–7 interview" as measured "at age 4–5" and, similarly, to human capital measures "before age 8–9 interview" as measured "at age 6–7".

Table 2 summarizes descriptive statistics for the child's skills and health, reporting both the standardized and raw values of these measures (see top and bottom panel, respectively). Because the standardization of the scores is carried out using the full sample of children responding at each stage, whereas the descriptive are reported for our sample of 1313 children, the standardized scores have a mean very close, but not exactly equal, to 0 and a standard deviation of about 1. We also measure the correlation between the different dimensions of the child's human capital (using standardized scores) and we find that generally it is low and not always significant. While emotional skills are positively and significantly correlated with both cognitive skills and physical health (Pearson coefficients are 0.11 and 0.29 respectively), physical health does not appear to be significantly correlated with cognitive skills. These findings confirm the importance of including separate measures of the child's skills in the model that account for the multidimensionality of human capital.

3.4. Additional variables

In the top panel of Table C1 in the online appendix, we report descriptive statistics for the time variant covariates, which are obtained by averaging them across the child's life stages 1 and 2 (age 6–7 and 8–9).

Children are, on average, 93.5 months (7.79 years). The yearly household income, measured in thousands of Australian dollars at 2003 constant prices (calculated using the consumer price index) and equivalised to account for the household composition by using the OECD modified scale,[16] is on average equal to 39689 Australian dollars.

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

[16] 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.

Family shocks are defined using four dummies indicating whether, in the year before the interview, the child experienced a serious illness, injury or assault directly affecting (i) one of the parents, (ii) close relatives or friends; or a death of (iii) grandparents or siblings, (iv) other family members or close family friends. We also consider a dummy taking value 1 if in the same period a new baby was born in the household, and zero otherwise. Of the children in the sample, 6.1 per cent have experienced a serious health issue affecting one of the parents and 10.2 per cent and one of close relative or family friends. About 3.6 per cent of children have experienced the death of a grandparent or sibling, while 18.4 per cent had a close family friend or relative who died. Finally, a new baby was born in 6 per cent of the households.

Regular childcare, which consists mostly of before- and after- school care, is classified as formal, informal or parental care. Formal childcare is offered in schools, day care centres and family day-care centres. On the contrary, informal childcare is defined as home-based care provided by grandparents, other relatives and nannies. Finally, parental care refers to those cases where children do not regularly attend any type of formal or informal childcare.

Childcare is measured using a set of four variables: a dummy for formal care which takes value 1 if the regular (main) type of childcare used is formal, and zero otherwise, an equivalent dummy for informal childcare (parental care is left out as reference category), the number of hours spent in formal care for those children whose main arrangement is formal care and the number of hours spent in informal care for those children whose main arrangement is 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 15.8 per cent of cases, and parental childcare for the remaining 65 per cent of children.[17]

Other time-varying variables we use in the sensitivity analyses include dummies indicating mothers' and fathers' working status (whether they work or not), the number of worked hours in a week (18.45 and 45.37 for mothers and fathers, respectively), an indicator for mothers with an university degree and the Kessler psychological distress scale, which proxies mother's mental health.

The middle part of Table C1 shows the mean and standard deviations for selected time-invariant child's and mother's variables, measured when children are 8–9 years old. In our sample, about 50 per cent of children are male, they live in households with an average of 2.6 children, and 14 per cent of them have been admitted to a neonatal intensive care unit at birth or special care nursery after they were born. Mothers' socio-economic status is proxied by education level, while employment status (measured using a dummy for working mothers, with the reference category being inactive or unemployed) is included as a measure of time constraint that affects the amount of time mothers can spend with their children. 41 per cent of mothers have at least a university degree, and 20 per cent are inactive or unemployed.

In the bottom part of Table C1, we report the descriptive statistics for time-varying school inputs, which are calculated on a smaller sample. We find the average pupil-teacher ratio be 20.8; 23.69 per cent of children attend catholic schools, 13.56 per cent attend private schools, and the remaining 62.75 per cent are registered in government schools.

4. Main results

4.1. Results on all types of time inputs

Tables 3 and 4 show the estimates of the time investment model (Eq. 5) with different types of time inputs as dependent variable. Table 3 focuses on the child's total time allocation, regardless of whom the child was with. More precisely, we divide the whole set of activities that a child has been recorded to do in 9 categories and define 9 corresponding time inputs, which are the time a child spends in school, learning, socialising, exercising, quietly playing, using media, basic care, sleeping, and other activities.[18] Table 4 focuses, instead, on the time children spend with their parents in the same activities except school, sleeping and "others".[19] For comparison with earlier papers that focused on parental time investments (see, e.g., Price, 2008; Hsin, 2009; Del Boca et al., 2014), we also include in Table 4 a measure of total parental time spent with children, which is given by the sum of the time spent by parents with the child in all the 9 activities except school, sleeping and others activities.

Each time input is measured in minutes per week and is regressed on the following set of explanatory variables: (i) three measures of the child's human capital (physical health, cognitive and socio-emotional skills), standardised to have a mean of zero and a variance of one, (ii) yearly equivalised household income in 1000 Australian dollars at 2003 constant prices, (iv) child's age in months and (v) childcare inputs (two dummies indicating whether formal or informal childcare is the main childcare arrangement, and the number of hours the child spends in the main type of childcare, expressed as deviation from the mean).[20]

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[17] Note that parents are asked to report only the main form of childcare. This means that the three categories of childcare are mutually exclusive and do not include any occasional use of childcare.

[18] Other activities (hereafter "others") is a residual category. See Table A1 for a detailed definition of all the activities.

[19] We exclude the time spent by the child with her parents in school, sleeping and others activities because the presence of parents for these activities is less relevant.

[20] When including additional controls for mother's human capital, parents' labour supply and school characteristics, we do not find any statistically significant effect for these extra variables (see Section 5.5).

Table 3
Models for child's total time spent in different activities.

Dependent variable	Cognitive skills	Socio-emotional skills	Physical health	Endogeneity test (p-value)
School time	-15.432	-12.860	-39.307	0.550
	(31.919)	(49.693)	(36.278)	
Learning time	-39.814**	-21.932	-2.555	0.001
	(19.864)	(46.357)	(24.670)	
Socialising time	19.070	-56.391	36.739	0.133
	(25.112)	(39.095)	(28.541)	
Exercising time	-5.367	32.208	15.393	0.280
	(20.325)	(31.643)	(23.101)	
Play time	-5.575	-16.786	15.450	0.748
	(13.285)	(20.683)	(15.099)	
Basic care time	15.627*	-3.070	2.924	0.916
	(9.192)	(14.310)	(10.447)	
Media time	-0.374	55.724**	-6.811	0.350
	(16.192)	(25.208)	(18.403)	
Sleep time	6.061	15.760	9.371	0.132
	(22.150)	(34.483)	(25.174)	
Time in other activities	-5.745	-16.703	-13.694	0.724
	(16.100)	(25.064)	(18.298)	
F-tests (first stages)	192.7	76.44	170.8	
N. children		1313		

Notes. Standard errors are in parentheses. *** p <0.01, ** p <0.05, * p <0.1. Each row refers to a different model for a specific time investment, measured in minutes per week, and shows the results of the child fixed effect estimation with IV (without IV) if the endogeneity test's p-value is below (above) 5%. Besides the three endogenous standardised measures of child's human capital, whose effect is reported by column, other controls include income, child's age and a set of variables for the childcare arrangements. The instruments for the model expressed in first difference are the double-lagged human capital measures. The first stage equations of the IV estimation are identical across all time inputs and the F-tests for the significance of the instruments for each of the human capital measures are reported in the bottom panel.

Table 4
Models for child's time spent with parents in different activities.

Dependent variable	Cognitive skills	Socio-emotional skills	Physical health	Endogeneity test (p-value)
Learning time	-9.034	19.534	3.387	0.651
	(15.074)	(35.179)	(18.721)	
Socialising time	-20.493	231.153***	23.370	0.004
	(33.450)	(78.064)	(41.543)	
Exercise time	0.529	26.721	-14.449	0.160
	(15.395)	(23.967)	(17.497)	
Play time	-10.805	6.238	7.933	0.739
	(10.318)	(16.064)	(11.727)	
Basic care time	-0.504	12.399	-0.108	0.531
	(9.431)	(14.682)	(10.719)	
Other time	-9.411	-12.063	2.213	0.732
	(9.049)	(14.088)	(10.284)	
Media time	1.407	36.526*	7.317	0.796
	(13.774)	(21.443)	(15.654)	
Total parental time	-19.561	499.858***	68.740	0.013
	(61.492)	(143.507)	(76.370)	
F-tests (first stages)	192.7	76.44	170.8	
N. children		1313		

Notes. Standard errors are in parentheses. *** p <0.01, ** p <0.05, * p <0.1. Each row refers to a different model for a specific time investment, measured in minutes per week, and shows the results of the child fixed effect estimation with IV (without IV) if the endogeneity test's p-value is below (above) 5%. Besides the three endogenous standardised measures of child's human capital, whose effect is reported by column, other controls include income, child's age and a set of variables for the childcare arrangements. The instruments for the model expressed in first difference are the double-lagged human capital measures. The first stage equations of the IV estimation are identical across all time inputs and the F-tests for the significance of the instruments for each of the human capital measures are reported in the bottom panel.

We estimate separate models for each time input using two types of estimations, the child fixed effect estimation with and without instruments, where the instruments are used to correct for the potential erogeneity of the child human capital measures caused by either unobserved variables or by reverse causality.[21]

Tables 3 and 4 report the results for the preferred estimation, namely the child fixed-effect estimation when the test for the absence of endogeneity does not reject the null hypothesis at 5% level (i.e. when the p-value reported in the last column is above 0.05)[22] and the estimation with child fixed effect and instrumental variables otherwise. Nevertheless, for transparency, we also report in Tables C4 and C5 in the online appendix the full set of results for both estimations methods.

Table 3 shows that parents react to a reduction in child's cognitive skills by increasing the allocation of the child's total time to learning activities.[23] More specifically, for one standard deviation decrease in child's cognitive skills, the time spent in learning activities increases about 40 minutes per week. The only other time input in Table 3 that reacts statistically significantly at the 5% level[24] to the child's human capital is media time, showing that for one standard deviation increase in child's socio-emotional skills the child's total time spent watching TV, using PC or other technological devices increases of about one hour per week.

The results in Table 4, where we consider the time children spend in different activities with their parents, indicate that, for one standard deviation decrease in socio-emotional skills, parents reduce the time they spend with their child socialising (visiting people and going to places) by about 4 hours per week and the time using media by about half an hour. This parental response is statistically significant at the 5% level for socialising time but only at a 10% level for media time. When looking at the total time parents spend with children (see last row in the top panel), we find a reinforcing effect for child socio-emotional skills, a result probably driven by socialising time.

In the bottom part of Tables 3 and 4, 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, that is, in the regression of each of the three measures of human capital on the instruments, while controlling for child fixed-effects and covariates (see Table C6 in the online appendix for the full set of first stage results). Notice that the first stage regressions for the three child's human capital measures are identical across all time inputs. Given the large F-statistics, we strongly reject the assumption of a zero effect of the instruments in each of the first stage equations.

Summarising, the results in Tables 3 and 4 suggest that parents compensate for low cognitive skills by allocating more child's time to learning activities, they reinforce for high socio-emotional skills by investing more time with the child socialising, and they seem also to allow the child to spend more (less) time using media, such a watching television, playing video-games and listening to music, when their child's socio-emotional skills are higher.

The only child's human capital measure to which parents do not seem to react is physical health. This result is likely to be driven by the fact that our time investments are not direct investments in health except for exercise time. Furthermore, the measure we use to proxy child's physical health captures conditions which do not vary significantly over time. This implies that there is little variation left in the health measure once controlled for the child fixed effect. An alternative approach consists in focusing on short-term measures of child's health, such as whether the child was ill when the information on parental behaviours was collected. When we use this type of measures we do find that parents react. However, the response seems to be a mechanic reaction caused by the child being unable to attend school and engage in usual activities, rather than an investment decision.[25] Finally, it may also be that parents do not alter the time allocation of their children as a reaction to changes in child's health because they prefer to change other types of investments such as the money spent on medical treatments and on the purchase of medicine or health products (Yi et al., 2015).

While so far we have defined parental time as the time children spend with either of the two parents or with both parents, it may be interesting to distinguish between mother's and father's time investment reactions to changes in child's human capital, as there is evidence that the father's time is more relevant during middle childhood than in early childhood (Del Boca et al., 2014). In Table C7, we provide the results obtained when we use as dependent variables: (a) father time only, if the father (but not the mother) is with the child, (b) mother time only, if the mother (but not the father) is with the child, (c) both parents time if both the mother and the father are there. To define these time investments, we consider the total time spent in learning, socialising, exercising, quietly playing, basic care and using media, similarly to what we do for the total parental time (last row of Table 4). The reinforcing strategy we observe for child's socialising skills in Table 4 seems to be driven by the total time a child spends with both mother and father present.

[21] A concern with our specification is that time inputs models are estimated separately and do not impose the sum of these time inputs to be equal to the total time in a week. However, we compare our results with those obtained when considering an estimation approach that imposes such restriction. More specifically, we use fractional multinomial logit models estimated by quasi maximum likelihood, where the dependent variables measure the time spent in a week by the child in different groups of activities divided by the total time (i.e. the proportion of time spent in each group of activities). We take account for the potential correlation between the individual (child) fixed effect and the explanatory variables by adopting a Mundlack (1978) correction approach and for the correlation in the error term within individuals by using a robust estimation of the standard errors. The results, available upon request, are similar to those presented in Table C4, both in terms of the direction of the effects as well as regarding the statistical significance of the coefficients.

[22] The test used for the endogeneity is a robust Durbin-Wu-Hausman test.

[23] By child's total time we always refer to the time the child spends in a set of activities, regardless of whom the child is with.

[24] Henceforth, references to 'statistical significance' indicate results that are statistically significant at the 5% level, if not otherwise stated.

[25] Results obtained using measures of short-term child illness, which we proxy with the number of days the child was ill in the week when the time-use dairies were filled, are available upon request from the authors.

Table 5
Models for learning and socialising time: Benchmark results.

	Cognitive skills	Socio-emotional skills	Physical health
Dependent variable: Learning time			
FE without IV	15.727	17.218	-3.368
	(10.888)	(16.951)	(12.375)
FE with IV	-39.814**	-21.932	-2.555
	(19.864)	(46.357)	(24.670)
F-test (first stages)	192.7	76.44	170.8
Endogeneity test		0.005	
No. children		1313	
Dependent variable: Socialising time with parents			
FE without IV	2.958	-7.561	5.694
	(18.061)	(28.118)	(20.527)
FE with IV	-20.493	231.153***	23.370
	(33.450)	(78.064)	(41.543)
F-test (first stages)	192.7	76.44	170.8
Endogeneity test (p-value)		0.004	
No. children		1313	

Notes. Standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The top and bottom panels report the results for fixed-effect estimation with instrumental variables (FE with IV) for the total time a child spends learning and the time a child spends with their parents socialising, measured in minutes per week (already shown in Tables 3 and 4), plus the fixed-effect estimation without IV (FE without IV). Besides the three endogenous standardised measures of child's human capital, whose effect is reported by column, other controls include income, child's age, and a set of variables for the childcare arrangements. The instruments for the model expressed in first difference are the double-lagged human capital measures. The first stage equations of the IV estimation are identical across the two time inputs and the F-tests for the significance of the instruments for each of the human capital measures are reported in the bottom panel together with the p-value of the robust Durbin-Wu-Hausman test for the exogeneity of the human capital measures.

4.2. Socialising and learning time

For the rest of our empirical analysis, we restrict our attention exclusively to time inputs that react statistically significantly at the 5% level to at least one of the three main measures of child's human capital (see Tables 3 and 4) and focus only on time inputs that can be viewed as productive investments in child development. While there are mixed results on the sign of the effect of media use on child's skills (Schmidt and Vandewater, 2008; Fiorini, 2010), Kalil et al. (2012) and Sokol et al. (2010) provide some evidence on the positive effects of learning and socializing activities on cognitive and socio-emotional development, respectively. Ultimately, this leads us to focus the rest of our analysis on the following two inputs:

1. *Learning time*: the total time the child spends with or without parents in learning activities, such as reading and private lessons;
2. *Socialising time*: the time the child spends with parents in socialising activities such as visiting people and going to places with parents.

Henceforth, for brevity, we will refer to these two time inputs directly as '"learning time"' and '"socialising time"'.

Table 5 reports the results for both child fixed-effect estimation with and without instrumental variables (FE with IV and FE without IV). In both cases, the preferred estimation is the FE estimation with IV given that the endogeneity tests reject the exogeneity of the human capital measures at 5%, and even at the 1% level. In all our further heterogeneity and sensitivity analyses for learning and socialising time, we report for brevity only the results for FE estimation with IV.

Looking at the effects of the remaining covariates on learning and socialising time in the second row of Tables C2 and C3, respectively, we do not find any statistically significant effect on learning time, while for the socialising time we find a negative trend in the child's age and an increase of 20 minutes for any extra hour in either formal or informal childcare.

It is no surprise that socialising time reacts to the child's socio-emotional skills and learning time to the child's cognitive skills. Nevertheless, it might be unexpected that while parents compensate for low cognitive skills by increasing the child's learning time, they do reinforce for low socio-emotional skills by reducing the socialising time. The reinforcing strategy adopted by parents for child's socio-emotional skills could be explained by the psychic cost (or mental effort) of socialising with a child who has behavioural problems (Cobb-Clark et al., 2019). It might be more difficult for parents to socialise with their children if they have conduct and hyperactivity problems (externalising behaviours) than if they adopt internalising behaviours, such as being withdrawn and depressed (emotional problems) or being solitary and with no friends (peer problems). We test this hypothesis by replacing our measure of child's socio-emotional skills, which consists on a composite

Table 6
Models for learning and socialising time: Using internalising and externalising behavioural measures.

Dependent variable	Cognitive skills	Externalising behaviours	Internalising behaviours	Endogeneity (p-value)
Learning time	-40.021**	-6.555	-20.361	0.008
	(19.876)	(47.529)	(26.355)	
Socialising time	-19.244	227.851***	60.952	0.008
	(33.505)	(80.119)	(44.426)	
F-stats (first stages)	144.9	50.51	111.7	
N. children		1313		

Notes. Standard errors are in parentheses. *** p <0.01, ** p <0.05, * p <0.1. The first and second rows report the results for fixed-effect estimation with instrumental variables (FE with IV) for the total time a child spends in learning activities and the time a child spends with their parents socialising (both measured in minutes per week). Besides the three endogenous standardised measures of child's human capital whose effect is reported by column, other controls include child's physical health (also treated as an endogenous measure), income, child's age and a set of variables for the childcare arrangements. The instruments for the model expressed in first difference are the double-lagged human capital measures. The first stage equations of the IV estimation are identical across the two time inputs and the F-tests for the significance of the instruments for each of the human capital measures are reported in the bottom panel together with the p-value of the robust Durbin-Wu-Hausman test for the exogeneity of the human capital measures.

score capturing both externalising behaviours (conduct and hyperactivity problems) and internalising behaviours (emotional and peers problems), with two separate indicators of socio-emotional skills measuring internalising and externalising problems, reversely coded so that higher values suggest fewer internalizing and externalizing behavioural problems. Looking at the results in Table 6, we do not find any response to either externalising or internalising behaviours for total learning time, but we find evidence of a reinforcing response for socialising time with parents that is mainly driven by child's externalising behaviour. This seems to confirm that parents adopt a reinforcing strategy for socialising time because it is difficult to socialise with a child who has more hyperactivity problems (such as being restless, overactive, and unable to stay still for long) or conduct problems (such as frequent tantrums and being generally disobedient).

4.3. Heterogeneity in the response of socialising and learning time

Parental decisions on the allocation of child's time to learning and socialising may be affected by time constraints, psychological strain and high opportunity costs that working parents face compared to non-working parents. Even if increasing the amount of time that children spend in learning activities does not require parents to physically be there, parents still need to devote time managing and monitoring the reallocation of the child's time from non-learning to learning activities. This reallocation effort can be costly for parents, especially working mothers, because of time constraints and the psychological strain they face. This is even more the case for time parents spend socialising with their child, as it requires a direct investment of time and effort from the parents.

In Table 7, we show the heterogeneity in the responses of learning and socialising time investments by working status of the mother.[26] The estimation results in the top panel of Table 7 for learning time indicate that parents compensate for changes in cognitive skills more if the mother does not work than if the mother works. Although this difference is not statistically significant, it seems to suggest that working mothers are less responsive possibly because of time constraints. Looking at the results for the socialising time in the bottom panel of Table 7, we find that parents spend more time with their child socialising when the child's socio-emotional skills are higher, especially if the mother works. The difference in this reinforcing response between working and non-working mothers, although not statistically significant at the 5% level, might be interpreted as evidence that the time spent with a child with low socio-emotional skills (e.g., with misconduct problems) has a psychic cost that is higher for a working mother, who is potentially more psychologically strained than a non-working mother. We also find that non-working mothers compensate for low cognitive skills by spending statistically significantly more time socialising with the child, which again might indicate that the mothers who work are more time constrained.

The response to the child's human capital of the learning and socialising time also may differ by parental education. Economic theory suggests that the opportunity cost of spending time with the child is higher for highly educated parents because of their expected higher productivity in the labour market and their forgone earnings (Becker, 1965). At the same time, parents with high education may be more likely to be involved in their child's education and better able to identify a child's developmental needs (Gimenez-Nadal and Molina, 2013). Parents also may simply have stronger preferences for child quality, leading to larger time investments (Hill and Stafford, 1974; Guryan et al., 2008) and potentially to a stronger

[26] We focus here on mothers because almost all fathers in our sample work.

Table 7
Models for learning and socialising time: Heterogeneous effects by mother's working status.

	Cognitive skills	Socio-emotional skills
Dependent variable: Learning time		
Non-working mothers	-98.669**	-68.806
	(43.971)	(92.700)
Working mothers	-23.970	-7.962
	(22.357)	(53.444)
F-test (first stages)		
Non-working mothers	81.61	40.11
Working mothers	99.40	38.03
Endogeneity test (p-value)	0.036	
No. children	1313	
Dependent variable: Socialising time with parents		
Non-working mothers	-176.397**	155.528
	(74.082)	(156.178)
Working mothers	21.985	254.259***
	(37.666)	(90.041)
F-test (first stages)		
Non-working mothers	81.61	40.11
Working mothers	99.40	38.03
Endogeneity test (p-value)	0.019	
No. children	1313	

Notes. Standard errors are in parentheses. *** p <0.01, ** p <0.05, * p <0.1. The top and bottom panels report the results for fixed-effect estimation with instrumental variables (FE with IV) for the total time a child spends learning and the time a child spends with their parents socialising (both measured in minutes per week). The models allow the effects of the three endogenous standardised measures of child's human capital (including physical health) to differ between non-working and working mothers (see first and second rows of each of the two top panels). Other controls include income, child's age, and a set of variables for the childcare arrangements. The instruments for the model expressed in first difference are the double-lagged human capital measures interacted with the dummy variables for working and non-working mothers. The first stage equations of the IV estimation are identical across the two time inputs and the F-tests for the significance of the instruments for each of the human capital measures are reported in the bottom panel together with the p-value of the robust Durbin-Wu-Hausman test for the exogeneity of the human capital measures.

compensating strategy. Our results show that highly educated mothers (i.e., mothers with a university degree) compensate more for cognitive skills than less educated mothers when looking at learning time, but the difference is not statistically significant (see top panel of Table 8). On the contrary, highly educated mothers reinforce statistically significantly more for socio-emotional skills than less educated mothers when considering the child's socialising time (see bottom panel of Table 8). This evidence seems to support the assumption that mothers with a degree have a slightly stronger preference for high child's cognitive skills or they are slightly more capable of identifying a child's cognitive developmental needs. At the same time, they bare a higher psychic cost of socialising with a child with behavioural problems.

Because parents' time resources are limited, their time investment response may be attenuated by the presence of more than one child in the household. To assess this, we allow for learning and socialising time to respond differently to the child's human capital measures in only-child families and in multiple-children families. We do not find any statistically significant difference in the learning and socialising time response between one-child and multiple-children families. Nevertheless, the results in Table 9 seem to suggest that parents with more than one child have a slight preference for child quality, as they tend to compensate more for low cognitive skills when looking at the child's learning time. At the same time, they seem more time constrained and tend to socialise less with their children if they have low socio-emotional skills.

Parents may have preferences for child quality which vary according to their child's gender. These preferences may lead to differences in the investment strategy adopted for sons and daughters. Table 10 shows the estimation results when allowing for heterogeneity of the effects of the human capital measures by gender of the child. Learning time compensates statistically significantly more for girls' than boys' cognitive skills, whereas there are no gender differences in the socialising time response. The difference between boys and girls in the learning time's response might also be driven by gender dif-

Table 8
Models for learning and socialising time: Heterogeneous effects by mother's level of education.

	Cognitive skills	Socio-emotional skills
Dependent variable: Learning time		
Mothers with no degree	-32.738	-22.313
	(26.044)	(60.301)
Mothers with degree	-52.061*	-41.148
	(30.723)	(73.214)
F-test (first stages)		
Mothers with no degree	95.63	38.99
Mothers with degree	98.80	37.20
Endogeneity test (p-value)	0.0346	
No. children	1313	
Dependent variable: Socialising time with parents		
Mothers with no degree	-57.971	101.109
	(44.644)	(103.367)
Mothers with degree	33.439	452.662***
	(52.665)	(125.502)
F-test (first stages)		
Mothers with no degree	95.63	38.99
Mothers with degree	98.80	37.20
Endogeneity test (p-value)	0.001	
No. children	1313	

Notes. Standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The top and bottom panels report the results for fixed-effect estimation with instrumental variables (FE with IV) for the total time a child spends learning and the time a child spends with their parents socialising (both measured in minutes per week). The models allow the effects of the endogenous standardised measures of child's human capital (including physical health) to differ between mothers without and with a degree. Other controls include income, child's age, and a set of variables for the childcare arrangements. The instruments for the model expressed in first difference are the double-lagged human capital measures interacted with two dummies for mothers with and without a degree. The first stage equations of the IV estimation are identical across the two time inputs and the F-tests for the significance of the instruments for each of the human capital measures are reported in the bottom panel together with the p-value of the robust Durbin-Wu-Hausman test for the exogeneity of the human capital measures.

ferences in attitudes and predisposition for reading and doing homework[27] rather than differences in parents' preferences across gender.

Finally, our results can inform us about the effect of time inputs on the child's human capital development. If parental time investments have a positive effect on child's skills, then the child FE estimation without IV would underestimate the effect of child's human capital with respect to the FE estimation with IV (see Equation (A14) in Appendix C). We find this to be the case for socialising time, which seems to have a positive feedback effect on socio-emotional skills of the child. However, we do not find evidence for a positive feedback effect of learning time on cognitive skills. Based on this evidence, we would conclude that interventions aimed at increasing the time parents spend with their children socialising could be effective to reduce gaps in socio-emotional skills.

5. Validity of the instrumental variable estimation

In this section, we discuss threats to the validity of our instrumental variable estimation and we assess the importance of measurement errors and model misspecification issues, including omitted variables, invariance and linearity assumptions.

5.1. Threats to the validity of our instruments

The validity of our instruments relies on the assumption of independence between the current level of child's human capital and the future idiosyncratic shocks affecting time investments, in particular the child's learning and socialising time (see basic assumption in Appendix C). In our empirical application this translates into an independence assumption between

[27] Girls have been found to have better attitudes to reading and tend to spend more time doing homework (see Torppa et al., 2018).

Table 9
Models for learning and socialising time: Heterogeneous effects by number of children in the household.

	Cognitive skills	Socio-emotional skills
Dependent variable: Learning time		
Only-child families	8.965	-7.018
	(93.627)	(182.280)
Multiple-children families	-42.243**	-21.456
	(20.545)	(48.635)
F-test (first stages)		
Only-child families	84.12	82.06
Multiple-children families	97.87	37.50
Endogeneity test (p-value)	0.021	
No. children	1313	
Dependent variable: Socialising time with parents		
Only-child families	-148.443	65.991
	(157.353)	(306.346)
Multiple-children families	-11.346	243.345***
	(34.528)	(81.737)
F-test (first stages)		
Only-child families	84.12	82.06
Multiple-children families	97.87	37.50
Endogeneity test (p-value)	0.033	
No. children	1313	

Notes. Standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The top and bottom panels report the results for fixed-effect estimation with instrumental variables (FE with IV) for the total time a child spends in learning activities and the time a child spends with their parents socialising (both measured in minutes per week). The models allow the effects of the endogenous standardised measures of child's human capital (including physical health) to differ between only-child and multiple-child families. Other controls include income, child's age and a set of variables for the childcare arrangements. The instruments for the model expressed in first difference are the double-lagged human capital measures interacted with the dummy variables for only-child and multiple-children families. The first stage equations of the IV estimation are identical across the two time inputs and the F-tests for the significance of the instruments for each of the human capital measures are reported in the bottom panel together with the p-value of the robust Durbin-Wu-Hausman test for the exogeneity of the human capital measures.

the three measures of child's human capital (cognitive and socio-emotional skills and physical health) observed at age 4–5 and the idiosyncratic error term in the time investment equation at ages 6–7 and 8–9.

Variation in the child's human capital at age 4–5 could be caused by early life inputs, which also could have a direct effect on future time inputs at ages 6–7 and 8–9. This variation does not bias our estimation because the direct effects of early life inputs do not change between investments at ages 6–7 and 8–9 (model invariance assumption)[28] and are therefore controlled for by our fixed-effect estimation. More generally, due to the child fixed-effect estimation we are able to control for any time-invariant observed and unobserved variable. Hence, the only reason our instruments could be invalid is because of unobserved time-varying characteristics which are correlated with changes in child's human capital between ages 4–5 and 6–7 as well as with changes in time investments between ages 6–7 and 8–9.

Parental decisions about childcare arrangements (number of hours and type of childcare), father's and mother's worked hours could depend on changes in the child's human capital between ages 4–5 and 6–7 and could also cause a change in child's learning and socialising time from ages 6–7 to 8–9. This implies that omitting to control for these parental decisions could invalidate our instrumental variables and lead to an endogeneity bias. Results on the effect of the three child's human capital measures remain unaltered when we exclude from the main specification the variables measuring the use of formal and informal childcare (see Table C8 in the online appendix), which suggests that these childcare variables are not endogenous in our model. We also find that controlling or not controlling for father's and mother's worked hours do not make any statistically significant difference in the estimated response of child's learning and socialising time to child's human capital. We discuss in more details the effect of including these as well as other additional explanatory variables at the end of Section 5.5.

[28] We test this assumption later in this section.

Table 10
Models for learning and socialising time: Heterogeneous effects by child gender.

	Cognitive skills	Socio-emotional skills
Dependent variable: Learning time		
Boys	12.438	-66.974
	(28.096)	(74.012)
Girls	-102.410***	14.093
	(29.331)	(57.906)
F-test (first stages)		
Boys	95.31	25.20
Girls	95.66	65.62
Endogeneity test (p-value)	0.001	
No. children	1313	
Dependent variable: Socialising time with parents		
Boys	16.554	300.552**
	(47.154)	(124.214)
Girls	-56.053	167.952*
	(49.227)	(97.185)
F-test (first stages)		
Boys	95.31	25.20
Girls	95.66	65.62
Endogeneity test (p-value)	0.029	
No. children	1313	

Notes. Standard errors are in parentheses. *** p <0.01, ** p <0.05, * p <0.1. The top and bottom panels report the results for fixed-effect estimation with instrumental variables (FE with IV) for the total time a child spends in learning activities and the time a child spends with their parents socialising (both measured in minutes per week). The models allow the effects of the endogenous standardised measures of child's human capital (including physical health) to differ between boys and girls. Other controls include income, child's age and a set of variables for the childcare arrangements. The instruments for the model expressed in first difference are the double-lagged human capital measures interacted with two dummies for boys and girls. The first stage equations of the IV estimation are identical across the two time inputs and the F-tests for the significance of the instruments for each of the human capital measures are reported in the bottom panel together with the p-value of the robust Durbin-Wu-Hausman test for the exogeneity of the human capital measures.

It is difficult to identify other parental inputs that cause a significant variation in parental time investments and which also vary between ages 6–7 and 8–9 in reaction to changes in the child human capital between ages 4–5 and 6–7. For example, parents could react to an increase in child's health issues related to obesity between ages 4–5 and 6–7 by changing the child's diet between ages 6–7 and 8–9; however, it is unlikely that this change in the diet causes a significant difference in the allocation of child's time to learning and socialising between ages 6–7 and 8–9. On the contrary, parental decisions such as enrolling the child in a school with a longer school day may have an effect on the time the child spends learning outside the school and possibly on the socialising time with parents. Changes in school enrolment, however, are unlikely to occur between ages 6–7 and 8–9. When we include dummies for the type of school in our models, we find that they have no statistically significant effects (see Section 5.5). In conclusion, we do not think that there are other parental decisions that can bias our instrumental variable estimation.

Another concern for the validity of our instruments is the occurrence of family shocks that affect child human capital at age 4–5 as well as future child's time inputs and with effects on these time inputs that vary between age 6–7 and 8–9. Two types of shocks that can have important effects on child development and time allocation are the birth of a new sibling and health shocks occurring to parents or other family members (Morefield et al., 2011; Adda et al., 2012; Westermaier et al., 2013; Ryan and Anna, 2015). To verify whether this could be an issue for our instrumental variable estimation, we account for these family shocks by adding to the investment models for learning and socialising time (Eq. 6), expressed in first differences, a set of five dummy variables (in levels) indicating (i) serious health issues occurred to parents, (ii) serious health issues occurred to close relatives, (iii) death of the child's grandparents or siblings, (iv) death of other family members or close family friends, (v) the birth of a new baby. In Panel A of Table 11 we report the estimation results of the learning and socialising time models including the estimated effects of these additional dummy variables. We find that the coefficients of these variables are not statistically significant at the 5% level (neither separately nor jointly). Furthermore, comparing the results in panel A of Table 11 with our main results in Table 5, we find no relevant differences in the effects of the child human capital measures on learning and socialising time.

Table 11
Models for learning and socialising time: Testing the validity of the instrumental variable estimation.

Dependent Variable	Cognitive skills	Socio-emotional skills	Endogeneity (p-value)
	Panel A: Additional shocks		
Learning time	-38.627*	-21.488	0.009
	(19.889)	(46.495)	
Socialising time	-22.841	242.692***	0.003
	(33.486)	(78.280)	
F-test (first stages)	188.1	73.87	
N. children		1,259	
	Panel B: Over-identified model		
Learning time	-37.067*	-9.505	0.010
	(19.758)	(45.565)	
Socialising time	-20.479	223.993***	0.004
	(33.284)	(76.758)	
F-test (first stages)	96.98	39.19	
N. children		1313	
	Panel C: Ordinary days		
Learning time	-35.342	-23.901	0.014
	(23.979)	(65.444)	
Socialising time	-37.627	210.438**	0.009
	(31.822)	(86.847)	
F-tests (first stages)	137.0	42.11	
N. children		835	

Notes. Standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The first and second rows of each panel report the results for fixed-effect estimation with instrumental variables (FE with IV) for the total time a child spends in learning activities and the time a child spends with their parents socialising (both measured in minutes per week). Besides the endogenous standardised measures of child's human capital (including physical health), each model also includes income, child's age and a set of variables for childcare arrangements. Panel A shows results obtained when including a set of dummies capturing family shocks. Panel B shows results from an over-identified model, where the instruments include, besides the double-lagged skills, also their interactions with a dummy for child's neonatal intensive care or special care nursery. Sargan test for the overidentified model has a p-value equal to 0.307 and 0.861 for learning and socialising time respectively. Panel C shows results when we restrict the sample to children whose parents filled the time use diaries in ordinary days. The instruments for the model expressed in first difference are the double-lagged human capital measures. The first stage equations of the IV estimation are identical across the two time inputs but not across panels and the F-tests for the significance of the instruments for each of the human capital measures are reported in the bottom of each panel. The p-value of the robust Durbin-Wu-Hausman test for the exogeneity of the human capital measures is reported in the last column for each different dependent variable.

5.2. Measurement errors issues

Our instrumental variable estimation could be biased if learning and socialising time suffer from measurement error that is non-random. In particular, we are concerned that time use diaries may be collected in days which do not represent the typical time allocation of the child. This can happen, for example, because diaries are filled during a holiday or when the child or a parent is sick. As a robustness check, we estimate the main benchmark models using the subsample of children observed in ordinary days. As shown in Panel C of Table 11, the estimated effects of the child's cognitive and socio-emotional skills and physical health are similar and not statistically significantly different from to the ones found in our benchmark estimation results (Table 5).

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

Table 12
Models for learning and socialising time: Controlling for measurement errors in the human capital measures.

Dependent variable	Cognitive skills	Socio-emotional skills	Endogeneity (p-value)
	Panel A: Average SDQ score		
Learning time	-55.345**	0.847	0.014
	(22.758)	(30.635)	
Socialising time	-47.257	202.436**	0.156
	(37.652)	(94.942)	
First stats (first stages)	145.0	61.98	
N. children		978	
	Panel B: SDQ reported by the teacher		
Learning time	-55.791**	1.060	0.007
	(22.800)	(30.446)	
Socialising time	-46.415	83.042*	0.343
	(37.330)	(47.023)	
First stats (first stages)	145.1	106.6	
N. children		978	
	Panel C: Alternative measure of cognitive skills		
Learning time	-42.982	-33.375	0.649
	(41.303)	(46.388)	
Socialising time	51.970	223.100***	0.009
	(69.951)	(78.564)	
First stats (first stages)	343.7	76.31	
N. children		1313	
	Panel D: Alternative instruments		
Learning time	-34.365	4.837	0.262
	(30.461)	(80.272)	
Socialising time	-24.730	337.055**	0.031
	(52.325)	(137.891)	
F-stats (first stages)	50.00	17.04	
N. children		1112	

Notes. Standard errors are in parentheses. *** p <0.01, ** p <0.05, * p <0.1. The first and second rows of each panel report the results for fixed-effect estimation with instrumental variables (FE with IV) for the total time a child spends in learning activities and the time a child spends with their parents socialising (both measured in minutes per week). Besides the endogenous standardised measures of child's human capital (including physical health), each model also includes income, child's age and a set of variables for the childcare arrangements. Panel A shows results when socio-emotional skills are measured by the average SDQ score reported by the mother and the teacher. Panel B shows results when socio-emotional skills are measured by the SDQ score reported by the teacher. Panel C shows results when cognitive skills are measured by a dummy for maternal concerns about child's language skills. Panel D shows results when using as IVs factors extracted from multiple measures of cognitive, socio-emotional skills and physical health (rather than the double-lagged human capital measures). The instruments for the model expressed in first difference are the double-lagged human capital measures. The first stage equations of the IV estimation are identical across the two time inputs but not across panels and the F-tests for the significance of the instruments for each of the human capital measures are reported in the bottom of each panel. The p-value of the robust Durbin-Wu-Hausman test for the exogeneity of the human capital measures is reported in the last column for each different dependent variable.

Because we have two repeated measures of child's socio-emotional skills available, the SDQ (Strength and Difficulty Questionnaire) scores derived from the mother's and from the teacher's interviews, we can consider the average of the two scores. By using this average rather than the SDQ score reported by the mother (which is the measure used for our main estimation results) we expect to reduce the measurement error. Under the classical measurement error assumptions, that is, under the assumption that the measurement errors in the two SDQ scores are uncorrelated with each other and uncorrelated with the true child's socio-emotional skills, the measurement error bias should reduce. Results obtained using the average of the two SDQ scores (panel A of Table 12) are similar to those obtained using the SDQ score reported by the mother (Table 5). This suggests that the bias caused by the measurement error is not a major concern when using the child fixed-effect instrumental variable estimation.

To further convince ourselves that the measurement error on socio-emotional skills is not an issue, we replace the SDQ score reported by the mother with the one reported by the teacher, which might be a more objective measure and therefore less affected by measurement error. We find similar, but slightly attenuated, results for the effect of socio-emotional skills (see Panel B of Table 12), suggesting that the mothers' beliefs on the socio-emotional skills of their child are not systematically different from the teachers' beliefs.

Because we measure child's cognitive skills using an objective test administered by the interviewer, the Peabody Picture Vocabulary Test, we wonder if this objective measure differs from parents' subjective beliefs about their child's cognitive skills. In Panel C of Table 12 we report the estimated response of the learning and socialising time when using a subjective measure of cognitive skill reported by the mother, which is a dummy taking value of 1 if the mother has concerns about her child's receptive language skills. We find a negative effect of cognitive skills on learning time, which, although not statistically significant, is indistinguishable from the effect found in our benchmark estimation. This result therefore suggests that parents have beliefs on their child's verbal skills that do not systematically differ from the objective measure of cognitive skills.

We also verify whether there is a bias in our estimation caused by measurement error in the human capital measures. We perform a separate factor analysis using two measures of cognitive skills, two of socio-emotional skills and seven of physical health observed when the child is 4–5 to derive latent factors which are free of, or at least less affected by, measurement error. To derive these factors for age 4–5, we use, beside our three standard measures of child's human capital at age 4–5, the following additional measures: a test assessing early literacy and numeracy skills (see De Lemos and Brian, 2000) called Who Am I (WAI); a standardised composite score derived from the Strength and Difficulty Questionnaire (SDQ) administered to teachers; two motor skills measures based on how the child's teacher rates the child's gross and fine motor skills compared to other children of similar age; and three indicators for whether the child needs or uses medicines prescribed by a doctor (other than vitamins), whether the mother has any concern about her child's weight, and whether she thinks that her child uses medical care more often than the average child. We retain one common factor for cognitive skills, one for socio-emotional skills and three for physical health.[29] We use these five factors as instruments for the differences in the human capital measures between age 6–7 and 4–5. As these instruments have no measurement errors (or smaller measurement errors), the estimation is more robust. Results are reported in panel D of Table 12 and are in line with our main results except for an increase in the standard errors.

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

Another potential issue with the human capital measures is that their scale is arbitrary and any monotonic transformation of these measures would possibly lead to different results. Each of our three human capital measures are given by the sum of multiple items and are standardised by age (4–5 and 6–7). When we consider the first difference in each of the human capital measures between ages 4–5 and 6–7, we could get negative values even when the child has improved her raw (unstandardised) skills. This is because the child's improvement could be below the increase for the remaining children in the sample. To check that using the standardised, rather than raw, measures does not lead to substantial different results, we report the estimated effects of the raw human capital measures on learning and socialising time in the top panel of Table C9. Similarly, to show that monotonic transformations do not alter our results, we report the estimated effect of the human capital measures after we apply a logarithm transformation in the bottom panel of Table C9. In both cases, we find results similar to our benchmark estimated effects. The sign and significance are identical and the coefficients are similar once we take consider that (i) the raw measures' effects should be multiplied by the standard deviation of the corresponding human capital measure to be comparable to the benchmark results, and (ii) the coefficients of the measures expressed in logarithms divided by 100 are interpretable as the effects on learning and socialising time of an increase of 1% in the raw measures.

5.3. Using additional instruments

To provide further evidence of the validity of the instrumental variables, we compute an over-identifying test (Sargan test) using additional instruments.

In the estimation based on factors used in the previous section (see Panel D of Table 12) we use five factors to instrument three variables and therefore we can perform a Sargan test for the over-identifying restrictions. The p-value of this test is 0.184 for the learning time and 0.595 for the socialising time models, suggesting that these factors are valid instruments.

We also consider an additional Sargan test by employing as instruments the child's human capital measures at age 4–5 and their interactions with a dummy which takes value 1 if the child had neonatal intensive care or special care nursery. These instruments are justified by the fact that a negative health shock at birth might affect the child development process. The estimated coefficients using the additional instruments are reported in Panel B of Table 11 and they do not seem to differ from our main results (Table 5). The Sargan test has a p-value of 0.307 and 0.861 for the learning and socialising time respectively, suggesting that we cannot reject the validity of the instruments used in the analysis.

[29] The amount of variance in each observed measure that is accounted for by the latent factor(s) is at least 37% for cognitive skills, 82% for socio-emotional skills and 28% for health measures.

Table 13
Models for learning and socialising time: Correlated random coefficients models.

Interactions	Cognitive skills	Socio-emotional skills
Dependent variable: learning time		
Hours in formal childcare	-54.344*	-23.419
	(21.142)	(49.512)
Hours in informal childcare	-44.726*	-16.028
	(25.399)	(47.716)
Income	-37.684*	-22.585
	(20.457)	(47.796)
Dummy for working hours	-31.432	-17.891
	(226.335)	(160.451)
Dummy for mothers with a degree	-39.863	-26.031
	(30.708)	(71.497)
Dummy for households with 1+ children	-46.119	-8.689
	(1614.269)	(584.848)
Dummy for child gender	-45.037	-24.837
	(79.746)	(78.116)
Dependent variable: socialising time		
Hours in formal childcare	-42.714	229.206***
	(35.750)	(83.721)
Hours in informal childcare	-11.062	247.113***
	(42.611)	(80.052)
Income	-14.811	233.807***
	(34.308)	(80.155)
Dummy for working hours	-16.662	233.168
	(335.528)	(237.859)
Dummy for mothers with a degree	-20.139	242.748
	(52.734)	(122.782)
Dummy for households with 1+ children	-20.283	233.393
	(1569.599)	(568.664)
Dummy for child gender	-17.110	235.434*
	(131.651)	(128.960)

Notes. Standard errors are in parentheses. *** p <0.01, ** p <0.05, * p <0.1. Each row reports the results of the fixed-effect estimation with instrumental variables of a different random coefficient model, which allows for a heterogeneous effect of the child's human capital measures by the variables reported in the column labelled 'Interactions'. The top and bottom panels consider as dependent variables the total time a child spends in learning activities and the time a child spends with their parents socialising (both measured in minutes per week), respectively. The average causal effect of each of the endogenous standardised measures of child's human capital is reported by column. Each model also includes physical health, income, child's age and a set of variables for the childcare arrangements.

5.4. Interpretation of the IV estimates

So far, we have assumed that the effect of child's human capital on the parental time investment is homogenous, but the response of parents to changes in their child's human capital could be heterogeneous. In the presence of such heterogeneity, the instrumental variable estimation would identify the average causal effect of the child human capital on parental time investment only for the sub-population for which the instruments cause a change in the endogenous human capital measures, that is, a local average treatment effect (see Imbens and Angrist, 1994; Heckman et al., 2006; Angrist and Pischke, 2009). To check whether such heterogeneity issue is a concern, we extend our investment model by considering a correlated random coefficient (CRC) model (see Wooldridge, 2003).

Details on this CRC model are provided in Appendix D; but, in short, the CRC model is an extension of our investment model (Eq. 6) which includes interactions terms between each of the human capital measures $\theta_{i,t}^k$ and some observed characteristics as well as interactions terms between $\theta_{i,t}^k$ and an unobserved error component ν_i^k, which we allow to be correlated with $\theta_{i,t}^k$ (essential heterogeneity). By using the instrumental variable estimation proposed by Wooldridge (2003), we estimate this CRC model and provide a consistent estimation of the average causal effects of the child human capital measures on the learning and socialising time for the full population, which we compare with our benchmark estimation results.

Because of the limited size of our sample, adding too many interaction terms in our time investment models would lead to imprecise estimates. For this reason, we decide to present results for CRC models that include interactions between the child human capital measures and one variable at time. In Table 13 we report the estimation results using these different CRC models. Each row corresponds to a specific CRC model and reports results of the three average causal effects, that is, the average effect of cognitive and socio-emotional skills and physical health on learning and socialising time in the top and bottom panels respectively. The variables used for the additional interactions in each model are reported in the column labelled 'Interactions'.[30] Focusing on the average causal effect of cognitive skills on learning time (see top panel of Table 13), we find estimated coefficients that vary between -31.3 and -64.24 and are well within the 95% confidence interval for our benchmark estimated coefficient, which is -39.814 with a standard error of 19.864. Similarly, for the average causal effect of socio-emotional skills on socialising time (see bottom panel of Table 13), we find estimated coefficients that vary between 229.21 and 247.11, which are almost identical to our benchmark estimated coefficient of 231.153 (with a standard error of 78.064). All other estimated average causal effects are smaller in magnitude and significance and suggest a zero effect, as in our benchmark instrumental variables estimation results in Table 5. We take this as evidence that our results hold also when taking into account the essential heterogeneity.

5.5. Testing model misspecification

The instrumental variables estimation also could be inconsistent if the time investment models are misspecified. In particular, we are concerned about three assumptions: (i) the linearity assumption of the time inputs in the human capital measures; (ii) the invariance assumption, that is, the assumption that the models for learning and socialising time do not vary across ages 6–7 and 8–9; (iii) the omission of relevant explanatory variables. In the following we test in sequence the validity of each of these three assumptions.

Parents might react more to changes in their child's human capital measures between age 4–5 and 6–7 if they lead to a low level of human capital at 6–7. To test if this is the case, we relax the assumption of linearity in the human capital measures and interact each measure of child human capital with a dummy, which takes a value of 1 if the child's level of skill is above its median at age 6–7 and zero otherwise. The reaction of the learning (socialising) time does not change statistically significantly between values of the cognitive skills (emotional skills) above and below the median (see Table C10). On the contrary, we find that learning time compensates for socio-emotional skills for values that are below the median and not for values above the median. However, such compensation effect is statistically significant only at the 10% level.

We test the invariance assumption empirically by estimating the models with child fixed effects (FE with no IV) and allowing the effects of the three measures of child's human capital on time investments at age 6–7 to differ from the corresponding effects on time investments at age 8–9. Although we can test the invariance assumption using the child fixed-effect estimation, we are unable to perform this test using the child fixed effect estimation with instrumental variables because the identification would require extra relevant instruments, which we do not have. Since the test of invariance based on the child fixed effect estimation is potentially invalid if the human capital measures are endogenous, we report the test applied to the model for media time, for which we do not reject the exogeneity of the human capital measures and we find a statistically significant response to the child's human capital. The invariance test suggests that we cannot reject the equality of the effects of the human capital measures on the media time at ages 6–7 an 8–9 at 10% or even 30% of significance (see column 3 in Table C11). For completeness, we also show the results of the invariance test applied to our benchmark models for total learning time and socialising time with the parents. The invariance test rejects the hypothesis of equal effects across time at the standard level of significance; but these rejections can be explained by the fact that the human capital measures are endogenous (see endogeneity test reported in Table 5) and therefore the fixed-effect estimation is inconsistent.

To ensure no relevant time-varying variables have been omitted, we run a set of sensitivity analyses showing that the results for the learning and socialising time do not change when including additional controls. More specifically, we add: (i) a dummy for whether the mother has a degree, (ii) a measure of mother's psychological well-being based on the Kessler psychological distress scale, (iii) mother's and father's work hours and dummy variables indicating if they worked, and (iv) school characteristics proxied by the pupil-teacher ratio and two dummy variables for catholic and private schools, with reference category being government schools (see Table C12). None of the additional variables has a statistically significant effect at 5% level and the responses of the two time inputs to the three human capital measures remain similar to the benchmark results (Table 5).

6. Conclusions

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

Estimating the response of time inputs to the child's skills is challenging because of the reverse causality and because of potential unobservables that may affect both the child's human capital and the parental decisions on how to allocate the

[30] These interaction variables are: hours in formal childcare, hours in informal childcare, income, dummy for working hours, dummy for mothers with a degree, dummy for households with 1+ children, dummy for child gender, dummy for first born children.

child's time to different activities. We tackle these issues using a child fixed-effect instrumental variable estimation in a way similar to the approach proposed by Rosenzweig and Wolpin (1995). Furthermore, we show that our approach is robust to a set of sensitivity analyses where we control for measurement errors and for the validity of the instruments.

We find two important results. First, parents react to changes in their child's human capital not only by varying the amount of time they spend with their offspring, but also by changing the allocation of the child's total time among different activities. Second, parental response differs across measures of child's human capital and types of time inputs. More specifically, when choosing the total time children spend in learning activities, parents compensate for the child's cognitive skills. On the contrary, socialising time with parents and total media time increase with the child's socio-emotional skills. As expected, when the child falls ill, the time spent in school and playing decreases, whereas the total time spent sleeping, media time and basic care time with parents rises.

Although these findings cannot provide us with a detailed specification of the underlying theoretical economic model, they suggest that it should (i) include different dimensions of the child's human capital as well as different types of parental investments, (ii) consider that parents may replace their time investments with time investments by other people, for example, time children spend with teachers or tutors.

If we believe that the total time children spend in educational activities and the time they spend socialising together with parents improves their cognitive and socio-emotional skills respectively, then our results can shed light on the long-term effects of interventions aiming at reducing the gap in human capital between high and low socio-economic status children. More specifically, our results suggest that interventions aiming at reducing the gap in child's cognitive (socio-emotional) skills by socio-economic status could have an effect that is attenuated (amplified) in the long-term by parents' compensating (reinforcing) investments. This could explain why early child programs, such as the Perry Preschool Program, have been found to have a positive effect on cognitive skills that is short-lived and a positive effect of socio-emotional skills that persists in the long term (see Heckman 2008).

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Appendix A. Definition of child's time in different activities

As detailed in Section 3, we employ two sets of measures of time investments. The first is defined as the weekly total time the child spends in each of the activities listed in Table A1. The second set is defined as the weekly time the child spends in the same set of activities, except school, sleeping and other activities, in the presence of one or both parents. The sum of all those time inputs in presence of parents, except media time, is our measure of the total time with parents.

All this information is obtained from the time-use diaries available in the Longitudinal Study of Australian Children (LSAC). Parents are asked to record in the time-use diaries the activities their child was engaged in for each of the 192 15-minutes intervals in two randomly allocated days. They are free to record multiple activities (up to 26) for each interval. However, differently from other time use surveys (such as the one in the Child Development Supplement of the Panel Study of Income Dynamics), LSAC does not distinguish between primary and secondary activities. To avoid double counting the time children spent when engaged in more than one activity at the same time, we follow an approach similar to the one employed in Fiorini and Keane (2014), by choosing for each 15-minute interval only the activity ranked first based on the following ordering:

1. school time,
2. socialising time,
3. learning time,
4. play time,
5. exercise time,
6. media time,
7. care time,
8. sleep time,
9. others time.

Table A1
List of activities considered for each of the child's time inputs.

Child time input	List of Activities
Schooling time	time spent at school
Learning time	• read a story, talk/sing, talked/sung to; • reading, looking at book by self • helping with chores/jobs • organised lessons/ activities
Exercising time	• organised sport/ physical activity; • quite free play; • walk for travel or for fun; • ride bicycle, trike etc (travel or fun); • other outdoor activities
Play time	quiet free play
Socialising time	• visiting people, special events, party; • taken places with adults (e.g. shopping)
Media time	• watching TV, video, dvd, movie; • listening to tapes, cd's, radio, music; • use computer, computer games
Basic care time	• eating, drinking, being fed; • bath, dress, hair care, health care; • held, cuddled, comforted, soothed; • being reprimanded, corrected
Sleeping time	sleeping, napping
Other time	• not sure what child was doing; • awake in the bed; • do nothing, bored/restless; • crying, upset, tantrum; • destroy things, create mess; • travel in car or other household vehicle; • travel on public transport

To deal with the problem of missing information on the type of activity for some of the 96 15-minute intervals, we adopt the following strategy. First, we record any spell between 9pm and 6am with missing information as sleeping time (similarly to Fiorini and Keane, 2014). Secondly, when the activity in an interval is missing but we know the child was outdoor, we classify that spell as "exercise time". Finally, we drop from the sample all children with missing information for more than 8 intervals out of the 96 15-minute intervals.

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

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

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

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

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

- *SDQ Hyperactivity subscale*: it is the average score for 5 parent-rated statements about the child's fidgetiness, concentration span and impulsiveness, which are:
  - restless, overactive, cannot stay still for long,
  - constantly fidgeting or squirming,
  - easily distracted, concentration wanders,
  - does not stop and thinks things out before acting,
  - does not see tasks through to the end, poor attention span.
- *SDQ Conduct subscale*: it is the average score for 5 parent-rated items assessing child's tendency to display problem behaviours when interacting with others and the 5 corresponding statements about the child are:
  - often has temper, tantrums or hot tempers,
  - not generally obedient, usually does not do what adult requests,
  - often fights with other children or bullies them,
  - often argumentative with adults,
  - can be spiteful with others.
- *SDQ Prosocial subscale:* it is the average score for 5 parent-rated items assessing the child's propensity to behave in a way that is considerate helpful to others, and the 5 corresponding statements about the child are:
  - considerate of other people's feelings,
  - shares readily with other children,
  - helpful if someone is hurt, upset or feeling ill,
  - kind to younger children,
  - often volunteers to help others.

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

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

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

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

Appendix C. Comparison of our econometric strategy with alternative estimations

We consider the following simplified investment model

$$I_{i,t}^{Time} = \alpha_0 + \theta_{i,t-1}\gamma + \mu_i + \epsilon_{i,t}, \tag{A1}$$

where $t = 1, 2$ and where we have omitted all explanatory variables except the child's human capital $\theta_{i,t-1}$, which we assume to be univariate, and we have maintained the same notation as in previous section.[31] Our instrumental variable estimation considers the above model expressed in first difference,

$$\Delta I_{i,2}^{Time} = \Delta\theta_{i,1}\gamma + \Delta\epsilon_{i,2}, \tag{A2}$$

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

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

$$I_{i,1}^{Time} = \alpha_0 + \theta_{i,0}\gamma + \mu_i + \epsilon_{i,1}, \tag{A3}$$

$$I_{i,2}^{Time} = \alpha_1 + \theta_{i,1}\gamma + \mu_i + \epsilon_{i,2}. \tag{A4}$$

[31] To generalize the model to include additional explanatory variables X we can use the Frisch-Waugh theorem and transform model A1 by premultiplying each of the variables in (A1) by the projection matrix onto the orthogonal complement of X. As long as the signs of covariances between the transformed variables are the same as the covariances for the original variables, our conclusions on the direction of the asymptotic bias of different types of estimation, reported below, remain valid.

The 7 moments conditions are derived by considering the second moments of the observed variables, $I_{i,t}^{Time}$ and $\theta_{i,t}$, and by using the models (A3) and (A4), under the basic assumption of no correlation between the idiosyncratic error in t, $\epsilon_{i,t}$, and the child's human capital in $(t-1)$. These 7 moment conditions are:

$$\sigma_{I_1}^2 = \gamma^2\sigma_{\theta_0}^2 + \sigma_{\mu}^2 + \sigma_{\epsilon_1}^2 + \sigma_{\theta_0\mu}\gamma, \tag{A5}$$

$$\sigma_{I_2}^2 = \gamma^2\sigma_{\theta_1}^2 + \sigma_{\mu}^2 + \sigma_{\epsilon_2}^2 + \sigma_{\theta_1\mu}\gamma, \tag{A6}$$

$$\sigma_{I_1I_2} = \gamma^2\sigma_{\theta_0\theta_1} + \sigma_{\theta_0\mu}\gamma + \sigma_{\theta_1\mu}\gamma + \sigma_{\mu}^2 + \sigma_{\theta_1\epsilon_1}\gamma, \tag{A7}$$

$$\sigma_{I_1\theta_0} = \gamma\sigma_{\theta_0}^2 + \sigma_{\theta_0\mu}, \tag{A8}$$

$$\sigma_{I_2\theta_0} = \gamma\sigma_{\theta_0\theta_1} + \sigma_{\theta_0\mu}, \tag{A9}$$

$$\sigma_{I_1\theta_1} = \gamma\sigma_{\theta_0\theta_1} + \sigma_{\theta_1\mu} + \sigma_{\theta_1\epsilon_1}, \tag{A10}$$

$$\sigma_{I_2\theta_1} = \gamma\sigma_{\theta_1}^2 + \sigma_{\theta_1\mu}, \tag{A11}$$

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

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

The fixed-effect instrumental variable estimation and the GMM estimation are equivalent because they both impose the same basic assumption and, contrary to other alternative estimation methods, they do not impose $\sigma_{\theta_0\mu}$, $\sigma_{\theta_1\mu}$, $\sigma_{\theta_0\epsilon_1}$ and $\sigma_{\theta_0\theta_1}$ to be equal to zero. The equivalence between the GMM and the fixed-effect instrumental variable estimation estimation has been already emphasized by Rosenzweig and Wolpin (1995) and Del Bono et al. (2012), who consider a different type of empirical application. They use repeated observations across siblings rather repeated observations for the same child across time and consider the reverse relationship.

Our FE-IV estimator converges in probability to

$$plim \quad \hat{\gamma}_{FE-IV} = \frac{\sigma_{\Delta I_2, P_{\theta_0}\Delta\theta_1}}{\sigma_{\Delta\theta_1, P_{\theta_0}\Delta\theta_1}} = \frac{\sigma_{\Delta\theta_1, P_{\theta_0}\Delta\theta_1}}{\sigma_{\Delta\theta_1, P_{\theta_0}\Delta\theta_1}}\gamma + \frac{\sigma_{\Delta\epsilon_2, P_{\theta_0}\Delta\theta_1}}{\sigma_{\Delta\theta_1, P_{\theta_0}\Delta\theta_1}}, \tag{A12}$$

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

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

$$plim \quad \hat{\gamma}_{POLS} = \frac{\sigma_{I_t\theta_{t-1}}}{\sigma_{\theta_{t-1}}^2} = \gamma + \frac{\sigma_{\mu\theta_{t-1}}}{\sigma_{\theta_{t-1}}^2}, \tag{A13}$$

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

$$plim \quad \hat{\gamma}_{FE} = \frac{\sigma_{\Delta I_2\Delta\theta_1}}{\sigma_{\Delta\theta_1}^2} = \gamma + \frac{\sigma_{\Delta\epsilon_2\Delta\theta_1}}{\sigma_{\Delta\theta_1}^2} = \gamma - \frac{\sigma_{\epsilon_1\theta_1}}{\sigma_{\Delta\theta_1}^2}, \tag{A14}$$

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

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

$$\theta_t = \theta_t^* + \omega_t, \tag{A15}$$

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

$$plim \quad \hat{\gamma}_{FE-IV} = \frac{\sigma_{\Delta I_2, P_{\theta_0}\Delta\theta_1}}{\sigma_{\Delta\theta_1, P_{\theta_0}\Delta\theta_1}} = \gamma[1 - \frac{\sigma_{\Delta\omega_1, P_{\theta_0}\Delta\theta_1}}{\sigma_{\Delta\theta_1, P_{\theta_0}\Delta\theta_1}}]. \tag{A16}$$

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

$$plim \quad \hat{\gamma}_{FE-IV} = \gamma[1 - \frac{(\eta-1)^2 Var(\omega_0)}{\sigma_{\Delta\theta_1, P_{\theta_0}\Delta\theta_1}}]. \tag{A17}$$

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

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

Appendix D. Estimation of the correlated random coefficient model

The correlated random coefficient (CRC) model for the parental investment is given by

$$I_{i,t}^{Time} = a_{i,t} + \boldsymbol{\theta}_{i,t-1}\mathbf{b}_i + e_{i,t} \tag{A18}$$

where, using the same notation as in Section 2.2, $I_{i,t}^{Time}$ denotes the time investment in stage t, with t taking values 1 or 2, $\boldsymbol{\theta}_{i,t-1} = [\theta_{i,t-1}^H, \theta_{i,t-1}^C, \theta_{i,t-1}^S]$ is the vector of the three measures of child human capital in stage $(t-1)$; whereas $e_{i,t}$ is the error term, and $a_{i,t}$ and $\mathbf{b}_i' = [b_i^C, b_i^S, b_i^H]$ are the random intercept and random slope coefficients.

We assume that the random intercept $a_{i,t}$ be time varying and depends on the observed time-variant variables $\mathbf{X}_{i,t}$, which are the same control variables we use also in the investment model (6), and on the observed time-invariant variable $\mathbf{W}_i$ in the following way

$$a_{i,t} = a_t + [\mathbf{X}_{i,t} - E(\mathbf{X}_t)]\widetilde{\boldsymbol{\beta}} + [\mathbf{W}_i - E(\mathbf{W})]\widetilde{\boldsymbol{\rho}} + \upsilon_{i,t}^a, \tag{A19}$$

where a_t is a time-varying fixed parameter which takes value $a_1 = \widetilde{\alpha}_0$ in stage 1 and $a_2 = \widetilde{\alpha}_0 + \widetilde{\alpha}_1$ in stage 2, $\widetilde{\boldsymbol{\beta}}$ and $\widetilde{\boldsymbol{\rho}}$ are vector of time-invariant parameters; $E(\mathbf{W})$ and $E(\mathbf{X}_t)$ are the population means of the observed time-varying and time-invariant variables; and $\upsilon_{i,t}^a$ is an unobserved random error component.

On the contrary, we assume that each of the random slope coefficients in $\mathbf{b}_i' = [b_i^C, b_i^S, b_i^H]$ be time invariant across stage 1 and 2 and follow the model

$$b_i^k = b_0^k + [\mathbf{W}_i - E(\mathbf{W})]\widetilde{\boldsymbol{\eta}}^k + \upsilon_i^k, \tag{A20}$$

where $k = C, S, H$; b_0^k and $\widetilde{\boldsymbol{\eta}}^k$ are parameters; and υ_i^k is an unobserved error component. Note that $\mathbf{W}_i$ can include the time-invariant part of variables that change across time (e.g. the average of $\mathbf{X}_{i,t}$ across stages 1 and 2).

By replacing the random coefficients $a_{i,t}$ and b_i^k in equation (A18) with the right hand side of equations (A19) (A20), we can rewrite the CRC model as

$$\begin{aligned} I_{i,t}^{Time} = \; & a_t + \boldsymbol{\theta}_{i,t-1}\mathbf{b}_0 + (\mathbf{X}_{i,t} - \overline{\mathbf{X}}_t)\widetilde{\boldsymbol{\beta}} + (\mathbf{W}_i - \overline{\mathbf{W}})\widetilde{\boldsymbol{\rho}} + \\ & \textstyle\sum_k [\theta_{i,t-1}^k (\mathbf{W}_i - \overline{\mathbf{W}})\widetilde{\boldsymbol{\eta}}^k] + \omega_{i,t}, \end{aligned} \tag{A21}$$

where we have replaced the means $E(\mathbf{X}_t)$ and $E(\mathbf{W})$ with the sample averages $\overline{\mathbf{X}}_t$ and $\overline{\mathbf{W}}$, $\mathbf{b}_0'$ is $[b_0^C, b_0^S, b_0^H]$ and the error term

$$\omega_{i,t} = \sum_k [\theta_{i,t-1}^k \upsilon_i^k] + \upsilon_{i,t}^a + e_{i,t}. \tag{A22}$$

Expressing model (A21) in first differences between stage 2 and 1, we get

$$\Delta I_{i,2}^{Time} = \widetilde{\alpha}_1 + \Delta\boldsymbol{\theta}_{i,1}\mathbf{b}_0 + (\Delta\mathbf{X}_{i,2} - \Delta\overline{\mathbf{X}}_2)\widetilde{\boldsymbol{\beta}} + \textstyle\sum_k \Delta\theta_{i,1}^k (\mathbf{W}_i - \overline{\mathbf{W}})\widetilde{\boldsymbol{\eta}}^k + \Delta\omega_{i,2}, \tag{A23}$$

where $\Delta\omega_{i,2} = \sum_k [\Delta\theta_{i,1}^k \upsilon_i^k] + \Delta\upsilon_{i,2}^a + \Delta e_{i,2}$. The first three addends in the right hand side of the CRC model (A23) are equivalent to the right hand side of the investment model (6). The difference in the CRC model is that it includes: (i) the interaction terms between each of the child human capital measures in first differences and the variables $\mathbf{W}_i$, (ii) the interactions between the unobserved error component of each of the slope coefficients and the three child human capital measures in first differences (which are included in the error term $\Delta\omega_{i,2}$). Similarly to the investment model (6), the CRC model is expressed in first differences so any time invariant variable drops from the specification. This is the reason why the time-invariant variables $\mathbf{W}_i$ enters in the CRC model only when interacted with the human capital measures.

We are interested in estimating consistently the average causal effect of $\boldsymbol{\theta}_{i,1}$, i.e. the average of the random slope coefficients across all households, $E(\mathbf{b}_i) = \mathbf{b}_0$.

The main issue with the estimation of the above CRC model is that the error term $\Delta\omega_{i,2}$ is correlated with $\Delta\boldsymbol{\theta}_{i,1}$. To solve this endogeneity issue, we adopt the instrumental variable estimation suggested by Wooldridge (2003). Similarly to our main estimation, we instrument $\Delta\boldsymbol{\theta}_{i,1}$ with $\boldsymbol{\theta}_{i,0}$; whereas we instruments $[\Delta\theta_{i,1}^k(\mathbf{W}_i - \overline{\mathbf{W}})]$ with $[\theta_{i,0}^k(\mathbf{W}_i - \overline{\mathbf{W}})]$. In the following we denote the vector of these instruments with $\mathbf{Z}_{i,2}$.

Wooldridge (2003) defines the assumptions needed for this type of IV estimation to be consistent, which adapted to our model (A23) are:

Assumption 1 $E(\Delta I_{i,2}^{Time} | \Delta a_{i,2}, \mathbf{b}_i, \Delta\boldsymbol{\theta}_{i,1}, \Delta\mathbf{X}_{i,2}, \mathbf{W}_i, \mathbf{Z}_{i,2}) = E(\Delta I_{i,2}^{Time} | \Delta a_{i,2}, \mathbf{b}_i, \Delta\boldsymbol{\theta}_{i,1})$;

Assumption 2 $E(\upsilon_i^k | \Delta\mathbf{X}_{i,2}, \mathbf{W}_i, \mathbf{Z}_{i,2}) = 0$ for $k = C, S, H$ and $E(\Delta\upsilon_{i,2}^a | \Delta\mathbf{X}_{i,2}, \mathbf{W}_i, \mathbf{Z}_{i,2}) = 0$;

Assumption 3 for $Cov(\Delta\theta^k_{i,1}\upsilon^k_i) = E(\Delta\theta^k_{i,1}\upsilon^k_i) = c_k$, $Cov(\Delta\theta^k_{i,1}\upsilon^k_i|\Delta\mathbf{X}_{i,2}, \mathbf{W}_i, \mathbf{Z}_{i,2}) = c_k$ for $k = C, S, H$.

Because $\upsilon^k_i = b^k_i - E(b^k_i|\mathbf{W}_i)$ Assumption 3 implies that $\Delta\theta^k_{i,1}$ and b^k_i are allowed to be correlated. By using assumption (3) we can write the CRC model (A23) as

$$\begin{aligned}\Delta I^{Time}_{i,2} = \quad & (a+c) + \Delta\boldsymbol{\theta}_{i,1}\mathbf{b}_0 + (\Delta\mathbf{X}_{i,2} - \Delta\overline{\mathbf{X}}_2)\widetilde{\boldsymbol{\beta}} + \\ & \textstyle\sum_k[\Delta\theta^k_{i,1}(\mathbf{W}_i - \overline{\mathbf{W}})\widetilde{\boldsymbol{\eta}}^k] + r_i + \Delta\upsilon^a_{i,2} + \Delta e_{i,2}\end{aligned} \tag{A24}$$

where the new intercept $(a+c) = a + c_C + c_S + c_H$ and the new error competent r_i is equal to $\sum_k[\Delta\theta^k_{i,1}\upsilon^k_i - E(\Delta\theta^k_{i,1}\upsilon^k_i|\Delta\mathbf{X}_{i,2}, \mathbf{W}_i, \mathbf{Z}_i)]$. Assumptions 1, 2, and 3 imply that the new composite error term is such that

$$E(r_i + \Delta\upsilon^a_{i,2} + \Delta e_{i,2}|\Delta\mathbf{X}_{i,2}, \mathbf{W}_i, \mathbf{Z}_{i,2}) = 0. \tag{A25}$$

which in turns implies that we can estimate consistently model (A24) and the average causal effects $\mathbf{b}_0$ by using as instruments the variables $\mathbf{Z}_{i,2}$.

Supplementary material

Supplementary material associated with this article can be found, in the online version, at 10.1016/j.euroecorev.2020.103491

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