Health status at birth and early childhood human capital. Evidence from the French ELFE cohort

January 30, 2020

Abstract

A blossoming economic literature focuses on the effect of poor neonatal health on childhood development. This paper examines the effect of health at birth on very early child development. With a simple theoretical model that integrates parental investment decision, we identify the mechanisms through which a better health condition improves child development and we emphasize how parental background can shape the effects of health. Then, we perform an empirical analysis for France over the period 2010 to 2011, using unique data from a recent child cohort called ELFE. Using an identification strategy based on an instrumental specification, the results indicate that health at birth have a causal effect on early child development. We find no empirical evidence for the existence of a severity effect according to which the adverse effects of a poor initial health conditions is higher for children in low income family or with poorly educated mother.

Keywords: Early Child Development, Health at birth, Human Capital, IV estimation.
JEL classification: C26; I14; I18

1 Introduction

The economic literature has well documented that investment in early childhood is the most powerful investment a country can make given its long term economic return and its opportunity to improve equity among agents.[1] Furthermore, early child development is a

[1] Currie and Almond (2011a) provides a survey of empirical works that emphasize the long-term consequences for human capital of event occurring before age five. The concept of dynamics complementarity presented in Cunha and Heckman (2007), according to which the return to investments during childhood increases with early child development, provides an explanation. Recently, Manuelli and Seshadri (2014) reveal that a large part of the cross-country differences in wealth are explained by differences in the quality of human capital.

priority area of work of WHO and UNICEF and the Commission on the first 1000 days of the child launched in September 2019 by the French President illustrates the importance to identify the determinants of early child development to well design efficient policy tools and to gain a better understanding of the mechanisms through which inequalities could be formed.

The health sector has a key role to play in early childhood development as health problems at birth might depress the formation of human capital (Currie, 2009). In this paper, we study how health at birth affects the early child development during the first year of life. We treat this question by adopting an economic approach in several respects. First, we focus on cognitive formation of children, an index for early child human capital. Second, we consider optimizing behaviors to assess theoretically the effect of health on child development and to examine how socio-economic family's status can influence the relationship. Third, we take into account the existence of a non-random assignment of health at birth.

(1) First, we know very little to date about the effects of poor neonatal health on cognitive development at very early age. We have strong evidence that poor initial health conveys a disadvantage in the first years of elementary school (Figlio et al., 2014), reduces academic outcomes from childhood to early adolescence (Bharadwaj et al., 2018) and affects negatively adulthood health and skills outcomes (Almond and Currie, 2011b; Almond et al., 2018). Nevertheless, we have little information about the potential roles for policy interventions in ameliorating this disadvantage during very early childhood.[2] Using recent data from the French Longitudinal Study of Children, ELFE - a rich cohort data set of children born in 2011 in France - allows to study the link between neonatal health to early child development in a highly developed country.

(2) Our second contribution consists of two related parts to identify various channels that can explain the effect of health on child development and to examine if and how health endowment and parental socioeconomic conditions interact to form child human capital. Economic approach teaches that endowment causes behavioral responses. Thus, we first develop a simple theoretical model with parental investment in children in line with the models of human capital formation proposed by Cunha et al. (2010). In this way, we appreciate the effect of health endowments at birth on human capital formation by considering optimizing behaviors of parent, in the form of time spent with children. Such

[2] Wehby et al. (2012) consider very early child development, between 3 and 24 months, but they focus on parental and household investments effects. They perform an empirical analysis for South America.

investment depends on parental socioeconomic status but also on child health endowment. Thus, health conditions affect human capital by two channels. A direct one, going through direct biological effects that increase the risk of learning disabilities, academic difficulties or behavioral problems. An indirect one, going through parental behavior. The net effect and the interaction between family's characteristics and health effect depends on human capital technology. We assume a general formalization to discuss the different possible cases.

The literature reveals that the socioeconomic environment during childhood is crucial. In particular, income gap in households with children translates into relative disadvantage early in life by affecting child development before age five (Currie and Almond, 2011a). As regards the interplay between health and family's environment, a part of this literature attempts to examine if poor health conditions affect children's development across socioeconomic groups differentially but no consensus emerges. Case et al. (2002) focus on health outcomes in the US and find that the negative health impact of chronic health conditions is more pronounced in low income families. Reversely, Currie and Stabile (2003) find that the effect of a health shock on Canadian children test score and future health does not differ across socioeconomic groups. A recent study of Wei and Feeny (2019) confirms this result. Authors find no evidence that Canadian children from low-income families suffer more from poor health at birth than those of high-income family. These studies do not provide clear theoretical funding to explain the economic intuition behind their results. Using theory allows to identify the mechanisms behind such interaction and hence to appreciate how poor health can inhibit skill formation.

(3) We then conduct an empirical analysis to test our prediction for France, using a unique dataset on the entire French territory of the ELFE cohort. We aim at analyzing empirically the consequences of health at birth on child development and shedding light on differential impact of health on human capital with respect to revenue and education. To conduct our empirical analysis we use causal identification. From an empirical point of view, the positive correlation between health and child development is well documented (see e.g Maggi et al., 2010), but empirical evidences for France are scarce. Beside, it is most difficult to identify the causal effect of these variables and hence the literature underlines the need to develop novel methods to improve our ability to estimate the causal effect of health on human capital (Roth, 2017). More specifically, there are several empirical challenges in estimating the causal effect of health on educational outcomes. For example, health at

birth is often correlated with other factors, such as wealth, (Shiko and Eskil, 2019), which are also likely to be correlated with parental characteristics, generating a potential omitted variable bias problem (Currie, 2011). Therefore, if wealthier families are sorting themselves into residential locations with good health condition, a naive ordinary least squares (OLS) analysis may overestimate the true effect of health due to the positive association between wealth and education. To mitigate selection and endogeneity problems and to infer the impact of health at birth on human capital, we first use rich set of socio-demographic control variable available in the ELFE database. Then, in line with an abundant literature that underlines the link between exposure to pollution and fetal health (see Almond and Currie, 2011b, for a survey), we use air pollution exposure during pregnancy as an instrumental approach. To the best of our knowledge, this is the first instrumental study on the impact of health on human capital to use pollution exposure as an instrument.

From our simple theoretical model, we predict that health conditions at birth improve early child development and that parental behaviors can mitigate or amplify this relationship. Concerning the influence of family's environment on the adverse effect of bad health endowments at birth, we conclude that rich families suffer less when birth endowments and family's wealth (in the form of income and/or education) are substitute to form early child human capital. Using the ELFE cohort, we identify a causal effect of health conditions at birth on early child development which is mainly due to biological effect. Then, we cannot conclude that there are inequalities in the impact of health at birth on child development, as we find no significant difference depending on parents' revenue nor education profiles; There is no evidence, for France, that lower family income exacerbates the incidence of poor health condition. Based on our theoretical prediction, this result means that neonatal health and parental inputs are not complements nor substitute to form early human capital. Finally, our analysis suggests that ability gap between socioeconomic groups does not open up through the channel of health during the first year of life in France. Hence, there is good reasons to hope that there is an equal access to resources supporting health in early childhood.

2 Theoretical framework

This section develops a stylized theoretical model to highlight the link between birth endowment and child development.

2.1 The basic setup

We focus on early childhood human capital whose quantitative importance to explain the wealth of the Nations as been emphasized by Manuelli and Seshadri (2014). Our first objective in this Section is to identify economic mechanisms explaining how and why child's health status, that characterizes birth endowment, affects early child outcome. We pay a particular attention to the child socioeconomic environment to examine this relationship. As recently underlined by Bharadwaj et al. (2018), the role of parents to understand the interplay between health endowment and human capital formation is crucial and not well studied. We provide a benchmark to describe the process of human capital formation during early lifetime taking into account parental investment. Following the recent literature that underlines the importance of investment in time during early childhood (see Francesconi and Heckman, 2016, for a review of the literature on child development and parental investment), we consider parental time input in line with Becker (1965).[3]

The population is composed by households that consist in adult parents and their child. Only parents take decision, they invest in their child because of altruism (Families pre-school-age investments). There are two types of parents $i = l, h$ that differ in terms of endowed wealth (it can be financial wealth or education). Child is characterized by his health endowment at birth and we do not consider the effect of parental characteristics on this endowment. Our objective is not to examine socioeconomic inequalities in health and their consequences, but rather to identify how parental wealth can affect the sensitivity of human capital formation to a given birth endowment. In theory, child human capital formation occurs mainly in two distinct stages: during early childhood and during school process. The formalization proposed in the literature assumes that human capital at each stage is a function of investments, initial endowments, the stock of skills of the previous stage and parental characteristics (see e.g Cunha et al., 2010). For the sake of simplicity, we adapt this formalization and assume a one-period model of childhood, meaning that inputs

[3] Our general theoretical predictions hold with a formalization of investment in good.

at any stages of childhood are perfect substitutes.[4]

Early childhood human capital are assumed to depend positively on three inputs: health endowment at birth H_i, a composite of the investment in time made by parents to child care e_i, and parental skills or wealth W_i. We follow Cunha and Heckman (2007) assuming a CES development technology to combine these inputs. Child development is thus governed by:

$$CD_i = \left(\lambda_1 e_i^{\frac{\sigma-1}{\sigma}} + \lambda_2 H_i^{\frac{\sigma-1}{\sigma}} + \lambda_3 W_i^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}} \quad ; \quad \sigma > 0 \tag{1}$$

with σ that captures the degree of substituability between inputs. For $\sigma < 1$ health endowment and investment are complements while for $\sigma > 1$ they are substitutes. From Equation 1, we see the importance of health endowment at birth for the formation of human capital. Indeed, identifying health condition as an input of early child development implies that a better health condition increases the return to childhood investment, i.e $\frac{\partial^2 CD_i}{\partial e_i \partial H_i} > 0$.

Parents i derive utility from their consumption c_i and from their child's development CD_i. Their altruism provide an inter-generational link. We assume a Cobb-Douglas utility function such that the adult choice consists in maximizing the following program:

$$\begin{aligned} & \max_{c_i, e_i} (1-\beta)\ln c_i + \beta \ln CD_i \ ; \ \ 0 < \beta < 1 \\ \text{s.t} \quad & W_i(1-e_i) = c_i. \\ & CD_i = \left(\lambda_1 e_i^{\frac{\sigma-1}{\sigma}} + \lambda_2 H_i^{\frac{\sigma-1}{\sigma}} + \lambda_3 W_i^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}} \end{aligned} \tag{2}$$

Our objective is to determine how health endowment affects child human capital at the equilibrium, meaning when we consider behavioral responses.

2.2 Interaction between child's health endowment and human capital

From program 2, the optimal investment e_i satisfies the following equality:

$$\lambda_1 e_i + \left(\lambda_2 H_i^{\frac{\sigma-1}{\sigma}} + \lambda_3 W_i^{\frac{\sigma-1}{\sigma}}\right) e^{1/\sigma} = \lambda_1 \beta (1-e_i)/(1-\beta) \tag{3}$$

[4] With a one-period model of childhood, we do not distinguish between early investment and late investment and hence do not consider dynamic complementarity. This is relevant as our focus is not on the life-cycle profile of investment.

The overall amount of parental resources spent on child stems from altruistic motive, captured by β, and depends on parental income W_i if it is complement or substitute to other inputs ($\sigma \neq 1$). Otherwise ($\sigma = 1$), parental income does not affect parental investment. This is because a higher level of wealth generates an income effect, that favors investment for children, and a substitution effect, that makes other investments more profitable. Both effects exactly compensate in our setting because of the Cobb Douglas utility function.

By using Equations 1 and 3 we have the equilibrium value for the child development.

Proposition 1 *We have $CD_i \equiv CD(W_i, H_i)$.*

1. *Our model predicts that health affects the child development though a direct positive effect $\left(\frac{\partial CD_i}{\partial H_i}\right)$ and through and indirect effect $\left(\frac{\partial CD_i}{\partial e_i} \times \frac{\partial e_i}{\partial H_i}\right)$, negative (resp. positive) when inputs are substitutes (resp. complements). The net effect is positive.*

$$\frac{dCD_i}{dH_i} = \frac{\partial CD_i}{\partial H_i} + \frac{\partial CD_i}{\partial e_i} \times \frac{\partial e_i}{\partial H_i} > 0 \tag{4}$$

2. *The return of a better health status on child development depends on family's characteristics when $\lambda_3 > 0$ and $\sigma \neq 1$. Child development is less (resp. more) sensitive to health endowment for rich families when inputs are substitutes (resp. complements).*

$$\frac{\partial \varepsilon_{CD_i/H_i}}{\partial W_i} \neq 0$$

with ε_{CD_i/H_i}, the elasticity of child development to birth endowment

$$\varepsilon_{CD_i/H_i} = \frac{\lambda_2 H_i^{\frac{\sigma-1}{\sigma}} + \lambda_1 e_i^{\frac{-1}{\sigma}} \frac{\partial e_i}{\partial H_i} H_i}{\lambda_1 e_i^{\frac{\sigma-1}{\sigma}} + \lambda_2 H_i^{\frac{\sigma-1}{\sigma}} + \lambda_3 W_i^{\frac{\sigma-1}{\sigma}}} \tag{5}$$

Our simple model shows that the effect of health endowment goes beyond a purely biological effect. It also includes the effect of responsive investments by parents. The effect of a change in health is reflected in changes in the birth endowment and in parental investment. Investment can increase or decrease depending on the characteristics of the human capital formation.

Another focus of is to ask whether there is heterogeneity in the effects of health. We thus examine if the return of a better health status on child development is higher for children with a good socioeconomic environment (i.e a higher W_i). As presented in Proposition 1, the elasticity of child development to health endowment, ε_{CD_i/H_i}, can differ among household when $\lambda_3 > 0$ and $\sigma \neq 0$. When these two conditions are satisfied, parental characteristics W_i affect directly the elasticity of child development to health endowment and indirectly by modifying the way health endowment affects investment ($\frac{\partial^2 e_i}{\partial H_i \partial W_i}$). Both effects depend on inputs characteristics. When they are complements, rich families suffer more from adverse birth outcomes while the poor families suffer more when inputs are substitutes. In the case in which parental wealth is not a direct argument for the child development formation ($\lambda_3 = 0$) or that inputs are not substitutes nor complements ($\sigma = 1$), there is no inequality: the return of a better health status on child development does not differ among socioeconomic profiles.

Our theoretical results serve to motivate and interpret the observational work that is discussed below.

3 Data and Empirical Strategy

3.1 Data and summary statistics

Health and human capital outcomes are drawn from a unique and detailed dataset - ELFE - compiled by epidemiologists for the entire France. The aim of the ELFE project is indeed to observe for 20 years a cohort of 18 300 children recruited in 2011, in order to better understand how perinatal conditions and the various aspects of environment affect children's development, health and socialization from the fetal stage to adolescence. The data we include use more than 10 000 children from the ELFE cohort interviewed in 4 waves in 22 regions. [5] Table 1 presents the summary statistics of the ELFE cohort covered in the data in France in 2010 and 2011.

We use key variables of the ELFE dataset to conduct our analysis. To define health status at birth we focus on birth weight and gestational age (M00X_POIENF, M00X_AGEGEST). Figure 1 shows the distribution of birth weight as well as the distribution of gestational age.

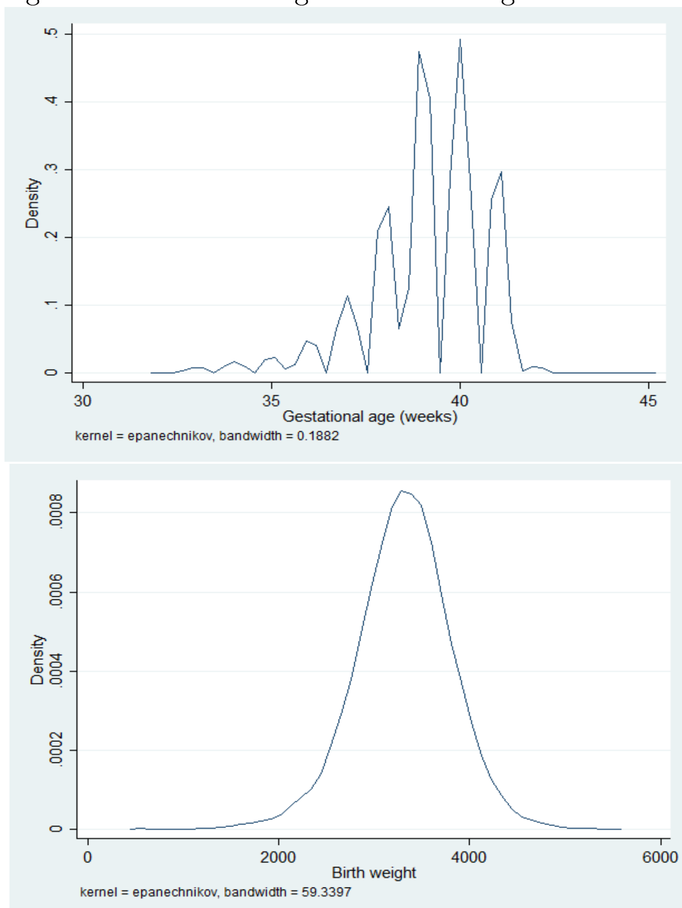
[5] The ELFE cohort represents babies born during four specific periods representing each of the four seasons in 2011: 1-4 April, 27 June - 4 July, 27 September - 4 October, and 28 November - 5 December.

Table 1: Summary Statistics

Variables	Description	mean	sd
	A. Dependent variables		
CD	Child development index (%)	85.32	9.85
TIME INVESTMENT	Time spent with child (%)	57.52	18.40
	B. Independent variables		
M00X_AGEGESTS	Gestational age (weeks)	39.16	1.50
M00X_POIENF	Birth weight (grams)	3308.90	499.28
	C. Control variables		
REV_PART	Average monthly income per household member (Eur)	1633.77	1009.29
MEDUC	Mother's education	3.79	1.22
M_AGE_2M	Mother's age	30.80	5.06
COUPLEMATRI_M_1A	Family status	2.96	2.14
HOUSE_TYPE	Type of housing at one year	1.45	0.51
M02M_TYPLOG	Type of housing at two months	1.46	0.61
URBAN	Urban area of living (=1 if yes)	0.55	0.50
M00M3_GYMPREN	Prenatal gymnastics	0.27	0.77
M00M3_MENPEN	Time spent to clean up	2.55	1.48
WORK_HOME_PREG	Work at home during pregnancy (=1 if yes)	0.04	0.19
MLENGHOME	Mother speaks french at home (=1 if yes)	0.94	0.23
FLENGHOME	Father speaks french at home (=1 if yes)	0.97	0.18
M02M_ENFSANT	Mother's perception of child health at two months	1.14	0.39
A01M_ENFSANT	Mother's perception of child health at one year	1.21	0.46
A01M_PBSANTE	Recognized health issues	1.98	0.19
SIB_1Y	Number of siblings	0.83	0.93
A01M_SEXEC1	Gender (=2 if male)	1.49	0.50
M00M1_NAISGEM	Twins (=1 if yes)	0.03	0.17
RANG_ELFE	Child ranking in ELFE cohort	1.83	1.01
A01E_PONDNONREF	Cohort ELFE weight (%)	67.82	60.37
	D. Instrumental variables		
PM10_T1	PM10 pollution concentration during 1st trimester of pregnancy (μg/m3)	25.60	6.91

Note: The time period covered in the analysis is 2010 and/or 2011, and the unit of analysis is the child - wave - region. There are 10393 observations in the studied sample. A detailed description of child development can be found in the Appendix Table 6.1.

Figure 1: Gestational age and birth weight distribution



Note: this figure shows the distribution of birth weight and gestational age using Kernel density estimate.

The distribution of birth weight as well as the distribution of gestational age are approximately normal justifying our empirical estimation in the next section.

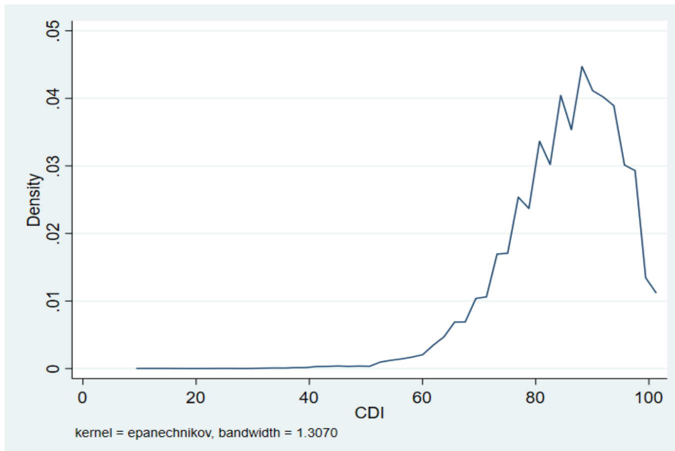
To capture early child development we use variables related to cognitive performance. More particularly, the ELFE cohort provides a number of questions that are used to define the Child Development Inventory based on the methodology of Ireton (1992). Respondent answers yes or no to each question.[6] We then define an index that corresponds to the percentage of positive responses in child development questions. The list of questions used to construct the child development is provided in Appendix 6.1. This constructed index is used as a proxy for child development.

Figure 2 shows the distribution of child development. Unsurprisingly, most of the re-

[6] We do not consider the one who does not answer to the questions. They are considered as "." in the analysis.

spondents respond positively to questions.

Figure 2: child development distribution



Note: this figure shows the distribution of child development using Kernel density estimate. A detailed description of child development can be found in the Appendix Table 6.1

Besides, literature argues that time parents spend with their child plays an important role on health (Rowe et al., 2016). Parent-child time can be seen as the form of human capital investment that prevails during early lifetime. Nevertheless, the link between parental time and early child outcome is poorly documented in the empirical literature, as reported by Wehby et al. (2012). Only recently, parental time investments in children have been introduced as an input in the formation of child outcomes. Del Boca et al. (2014), Del Bono et al. (2016) and more recently Bharadwaj et al. (2018) are important contributions but, these studies do not evaluated the effects of parental investments on very early ages outcomes. In this vein, we construct an index that takes into account the time parents spend with their own child (TIME INVESTMENT). To do so, we use several ELFE variables. The one year interview includes several questions about activities parents do with their children (small games, reading, drawing, tv, talking, singing, corporal game, others). These categorical variables give information about the time parents do often the activity. We construct a variable counting the number of time parents do often the activity in percentage of the number of questions and use it as another dependent variable in the estimation. In this way, we examine the various components that define the effect of health on child development as developped in the theoretical model (see Equation 4).

Then, we use several control variables recognized as determinants of health and cognitive development in the literature (Ouidir et al., 2017). For the family environment, we use the age of the mother (M_AGE_2M), average monthly income per household member, in Euro (REV_PART), french language at home (MLENGHOME; FLENGHOME), the type of housing when the child was two months and one year (M02M_TYPLOG, HOUSE_TYPE,)[7] and its location in the geographic area, rural or urban (URBAN). We also controls for mother's education[8] (MEDUC), as the mother's education is identified as an important determinant of the health of child (Chen and Li, 2009). Considering the result of Panico et al. (2019), such that family status correlates to children's early physical health, we also control for this dimension, distinguishing, notably, between married, cohabiting, divorced widowed and single parents (COUPLEMATRI_M_1A). We also includes behavioral variables to capture the behavior of mother during pregnancy (time spend to clean up, M00M3_MENPEN, or to do prenatal gymnastics M00M3_GYMPREN, or to work at home WORK_HOME_PREG).[9] We consider the perception of the health of the child by the mother, when the child is two months and one year (M02M_ENFSANT, A01M_ENFSANT).[10] We also control if child has a recognized health issue (A01M_PBSANTE).[11] We control for the number of siblings when the child is one year (SIB_1Y), for twin birth (M00M1_NAISGEM) and for the sex of the child (A01M_SEXEC1). We also add some technical control variables, specific to the ELFE cohort. The ranking of the child in the ELFE cohort (RANG_ELFE) and a weight variable (A01E_PONDNONREF).

We also dispose of pollution concentration during pregnancy. More precisely, each child has been matched with air pollution exposure during mother's pregnancy. The exposure to air pollutants was estimated by Riviere et al. (2019) using simulation models at the national and regional scale (CHIMERE). To our analysis, we consider particulate matter less than ten microns in diameter (PM10 air pollutant) which is commonly used when focusing on in utero pollution exposure.[12] The database thus constructed is unique in giving the health status and the child development status of each child with respect to air pollution exposure

[7]Mothers can choose between 3 items to define their location, 1 being an individual house, 2 an apartment and 3 other types.

[8]For mother education we have: 0 "none" 1 "primary" 2 "lower secondary" 3 "upper secondary" 4 "intermediate" 5 "higher".

[9]Mothers are asked to indicate how frequently they do the activity per week on a 6 point scale, ranging from 1 "never" to 6 "more than three hours per week".

[10]Respondent indicates whether the health of his child is: 1 "good", 2 "somewhat good", 3 "somewhat bad", 4 "‘bad", 5 "no answer", 6 "don't know".

[11]1 "yes", 2 "no", 3 "don't know".

[12]We focus on PM10, rather than PM2.5, because of larger database with the first one.

during mother's pregnancy. This exposure variable will be used as an instrument thereafter to investigate the causal effect of health at birth on child development.

3.2 Empirical strategy

As a baseline, we estimate first the following empirical model.

$$Y_{irw} = \alpha_0 + \beta_1 H_{irw} + \mu X_{irw} + \alpha_r + \varphi_w + \xi_{irw} \tag{6}$$

where Y represents child development or parental time investment for child i living in a region r and interviewed in wave w.[13] Coefficient β_1 measures the direct marginal effect of a child health status on Y_{irw}. H_{irw} is a health at birth variable that includes birth weight and gestational age. X_{irw} is a vector of child controls as described in the previous section and in Panel C of Table 1 . We also add temporal and spatial fixed effects. More particularly, we control for seasonal patterns by including the wave of the interview as a dummy variable (φ_w). In the same vein, α_r controls for time invariant specific regional characteristics. ξ_{irw} represents the error term.

Estimating equation 6 using the cross-sectional dataset at the child level would introduce measurement errors. While we control for several family characteristics linked with endogenous exposure to poor environmental quality, it may exist a number of unobserved factors that could influence both health and child development (as explained more precisely in the introduction). Then, we need to construct a measure of health endowment that addresses common endogeneity issues. Our identification strategy is an instrumental variable approach (IV). It consists of instrumenting child health endowment at birth with measures of PM10 air pollution exposure during pregnancy.[14] Hence, the main estimation relies on an IV specification to obtain an exact identification of the effect of health on child development.

As with any IV design, the key underlying assumption for identification is that the instrument serves as a valid instrument. Although we cannot explicitly verify this assumption, we feel this threat is limited in this setting for several reasons. We believe exposure to PM10 concentration of pollution during the first trimester of pregnancy are credible instrument as there are well correlated with birth outcomes. In fact, an abundant literature underlines the

[13] The unit of observation is the child.

[14] (Figlio et al., 2014) rely on twins fixed effect to address this problem. However, we only have 250 pairs of twin in the ELFE dataset precluding to do the same analysis.

link between exposure to pollution and fetal health (see Almond and Currie, 2011b, for a survey) . More specifically, a review of the literature from Maisonet et al. (2004) highlights that the risk of preterm delivery increases only for maternal exposures occurring during the first trimester of pregnancy. Consistent with this, later evidence from Lee et al. (2013) suggests that first trimester exposure to particles may increase the risk of preterm delivery as the fetus experiences important organ developments.

Birth outcomes should be the only factor explaining the impact of pollution on human capital for the exclusion restriction assumption to be valid. We believe exposure to pollution during first trimester of pregnancy has no influence on early child development apart through birth outcomes. The literature has identified the family's socioeconomic characteristics as key determinants of exposure to pollution and the ELFE dataset allows us to control for this dimension. The study of Graff Zivin and Neidell (2013) confirm this intuition. Hence, the exclusion restriction seems to be met. We then can estimate the following IV model:

$$H_{irw} = \alpha_1 + \beta_2 PM10_{irw} + \delta X_{irw} + \omega_r + \phi_w + \epsilon_{irw} \quad (7)$$

$$Y_{irw} = \alpha_2 + \beta_3 \hat{H}_{irw} + \mu X_{irw} + \alpha_r + \varphi_w + \xi_{irw} \quad (8)$$

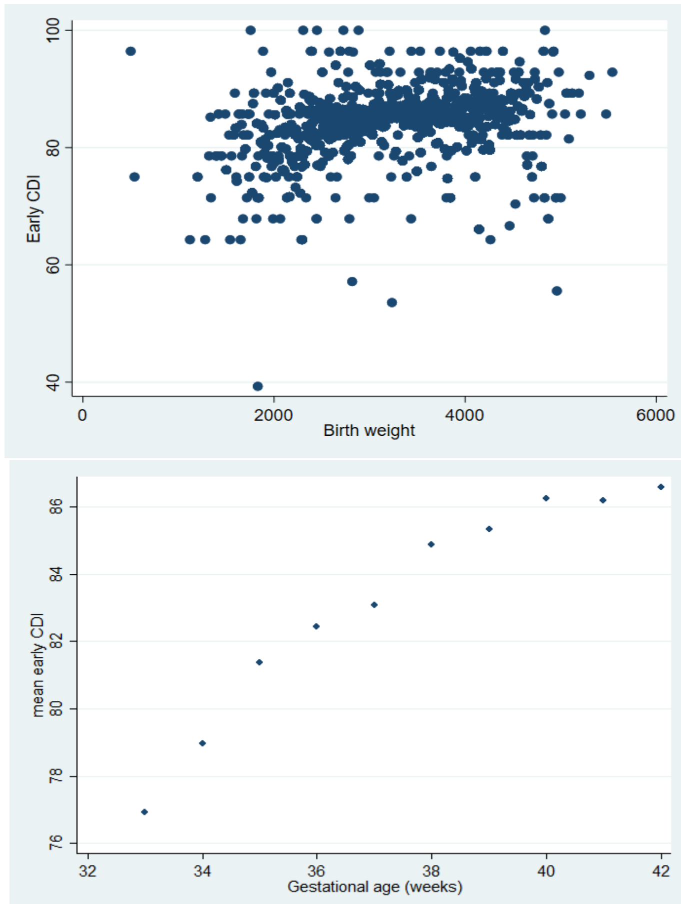
Where health of child i born in wave i, living in region r (H_{irw}) in Equation 8 has been instrumented by exposure to PM10 pollution during pregnancy of child i ($PM10_{irw}$) from Equation 7. Coefficient β_3 in Equation 8 represents our coefficient of interest and measures the causal effect of a child health status on child development. Both equations again rely on seasonal and regional fixed effects as well as a vector of controls for child characteristics.

4 Results

4.1 The impact of health on early child development

We start by examining the effect of health at birth on child development ($\frac{dCD_i}{dH_i}$ in the theoretical model). Figure 3 provides a scatter plot of the relationship between birth weight and child development as well as the relationship between gestational age and child development.

Figure 3: the relationship between early child development and birth weight or gestational age



Note: These figures plot the descriptive relationship between child development and birth weight or gestational age. The horizontal axis measures birth weight or gestational age. The vertical axis measures child development.

There is a straightforward relationship between gestational age and our index of child development; The child development has a strong positive relationship with gestational age: the higher the gestational age, the higher the index of child development. By contrast, this measure of human capital exhibits no clear association with birth weight.

Table 2 provides regression estimates of Equations 6 (OLS) and 8 (IV) which are largely analogous to this Figure. We present in Table 2, the results on the full sample using gestational age (Columns 1-3) or birth weight (Columns 4-6) like health indicators. Consistent with figure 3, Column 1 shows that the direct impact of gestational age is an increase in child development of 0.8 % on the full sample, when not controlling for child characteristics. We successively add more controls (i.e; namely child variables) and an IV estimation. Controlling for additional child characteristics slightly decreases the coefficient (0.6%). Column 3 shows estimation results using exposure to PM10 pollution during the first trimester of pregnancy as an instrumental variable. Adding an instrumental variable in Column 3 increases the effect further (2.3%). More precisely, we observe that a one week increase in gestational age increases child development by roughly 2.3% from the baseline mean. Table 2 repeats the exercise in Columns 4 to 6 using birth weight. Although very small, Columns 4, 5 and 6 show a positive impact of birth weight on child development. The effect is once again higher using IV estimation, and we particularly observe that a 100 grams increase in birth weight increases child development by roughly 1% from the baseline mean.

Turning to control variables, we observe being a girl has a positive impact on child development, in line with the literature that reveals the gender gap in educational attainment in favor of women (see Figlio et al., 2019, for a recent contribution). Our results suggest that the gender gap is observed very early. Mothers' age affects negatively child development. This is in line with the evidence showing that risk aversion increases with age (Hryshko et al., 2011) while parental risk aversion has a significant negative effect on children's educational attainment (Checchi et al., 2014). Living in an urban area increases significantly the impact of health on child development. Douthit et al. (2015) highlights it exists important barriers to health care access in rural areas. Doing activities such as prenatal gymnastics or spending time to clean up during pregnancy seems to favor child development in the OLS estimation. But this result does not hold using IV. In the opposite, twins birth has a negative impact on child development. Specific child health disabilities at one year decrease child development, and to a larger extent than does specific child health disabilities at two months. Mother's education nor household's income have a significant effect on child development in the model with control variables (Columns 2 and 4) and in the IV specification (Columns 3 and 5). A possible explanation is that these variables can affect child development through several channels (as described in the theoretical model) that can play in opposite direction. For example, the opportunity cost to invest in child differs among heterogeneous households, what can mitigate the assumed positive effect of income/education on child development[15]. Number of siblings, house type or household status have no impact on child development.

[15] The study of Del Boca et al. (2014) provides some arguments in this sense.

Table 2: The impact of health on child development

	Gestational age			BW		
	OLS	OLS	IV	OLS	OLS	IV
M00X_AGEGESTS	0.844***	0.659***	2.303*			
	(0.0644)	(0.0797)	(1.217)			
M00X_POIENF				0.00183***	0.00163***	0.0127*
				(0.000194)	(0.000241)	(0.00723)
REV_PART	-0.000255**	-0.000105	-0.000119	-0.000252**	-0.000112	-0.000195
	(0.000106)	(0.000144)	(0.000153)	(0.000107)	(0.000145)	(0.000160)
MEDUC	-0.0898	0.0962	-0.0317	-0.0537	0.112	-0.0643
	(0.0957)	(0.133)	(0.177)	(0.0965)	(0.134)	(0.207)
RANG_ELFE		-0.343	-0.423		-0.369	-1.015*
		(0.316)	(0.387)		(0.319)	(0.528)
SIB_1Y		0.465	0.609		0.343	0.0690
		(0.317)	(0.373)		(0.321)	(0.500)
M00M1_NAISGEM		-2.120***	1.127		-2.506***	5.167
		(0.726)	(2.933)		(0.724)	(5.419)
A01M_SEXEC1		1.499***	1.393***		1.776***	3.243***
		(0.218)	(0.259)		(0.222)	(1.013)
HOUSE_TYPE		0.854	0.659		0.955	1.041
		(0.584)	(0.589)		(0.587)	(0.640)
M00M3_GYMPREN		0.474***	0.232		0.489***	0.252
		(0.131)	(0.165)		(0.131)	(0.173)
M00M3_MENPEN		0.215***	0.0762		0.248***	0.166
		(0.0779)	(0.118)		(0.0784)	(0.103)
M02M_TYPLOG		-0.159	-0.00735		-0.203	-0.189
		(0.469)	(0.443)		(0.470)	(0.463)
M02M_ENFSANT		-0.488*	-0.176		-0.506*	-0.256
		(0.289)	(0.404)		(0.291)	(0.396)
A01M_ENFSANT		-1.089***	-0.931***		-1.081***	-0.741**
		(0.243)	(0.307)		(0.245)	(0.359)
A01M_PBSANTE		1.471**	1.328**		1.562**	1.925***
		(0.643)	(0.643)		(0.646)	(0.745)
COUPLEMATRI_M_1A		0.0816	0.115		0.102	0.217**
		(0.0649)	(0.0739)		(0.0655)	(0.102)
A01E_PONDNONREF		0.00375	0.00365		0.00388	0.00564
		(0.00285)	(0.00342)		(0.00287)	(0.00410)
URBAN		0.479*	0.164		0.531*	0.409
		(0.276)	(0.370)		(0.278)	(0.375)
WORK_HOME_PREG		0.950	0.894		1.005*	0.962
		(0.581)	(0.713)		(0.591)	(0.757)
M_AGE_2M		-0.169***	-0.193***		-0.161***	-0.124**
		(0.0295)	(0.0355)		(0.0298)	(0.0514)
MLENGHOME		-0.777	-0.927		-0.620	-0.0612
		(0.769)	(0.847)		(0.778)	(0.981)
FLENGHOME		-0.425	-0.287		-0.301	0.499
		(0.811)	(0.934)		(0.816)	(1.117)
Wave FE	YES	YES	YES	YES	YES	YES
Regional FE	YES	YES	YES	YES	YES	YES
N	10393	7332	5899	10272	7255	5833
r2	0.0490	0.0748	0.0237	0.0417	0.0723	.

Note: This table estimates the causal impact of gestational age and birth weight on cognitive development. The dependent variable is the Early child development. All estimations contain wave and regional fixed effect. Standard errors (in parenthesis)
Statistical significance is denoted by: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

As shown previously, our model predicts that health affects the child development though biological (health at birth) and behavioral responses (time investment). The previous Table 2 highlights that the net effect is positive. In order to disentangle both effects, we now estimate the impact of health on time investment, $\frac{\partial e_i}{\partial H_i}$, in Table 3. To do so we repeat the same exercise done in Table 2 replacing child development by time investment as a dependent variable. We find no significant effect of gestational age or birth weight on time investment in each of our specification.[16] This latter result means inputs (i.e: time investment, health at birth) are not complement nor substitute as discussed in the previous theoretical section. In relation to Proposition 4 from the theoretical section, empirical results show early child development in France does not depend on parental time investment, component of the change in child development related to health. Thus, the significant change in early child development related to health, $\frac{dCD_i}{dH_i}$, observed in Table 2, is only related to a purely biological effect, $\frac{\partial CD_i}{\partial H_i}$.

The next section aims to estimate the effect of gestational age and birth weight on child development with respect to socioeconomic characteristics.

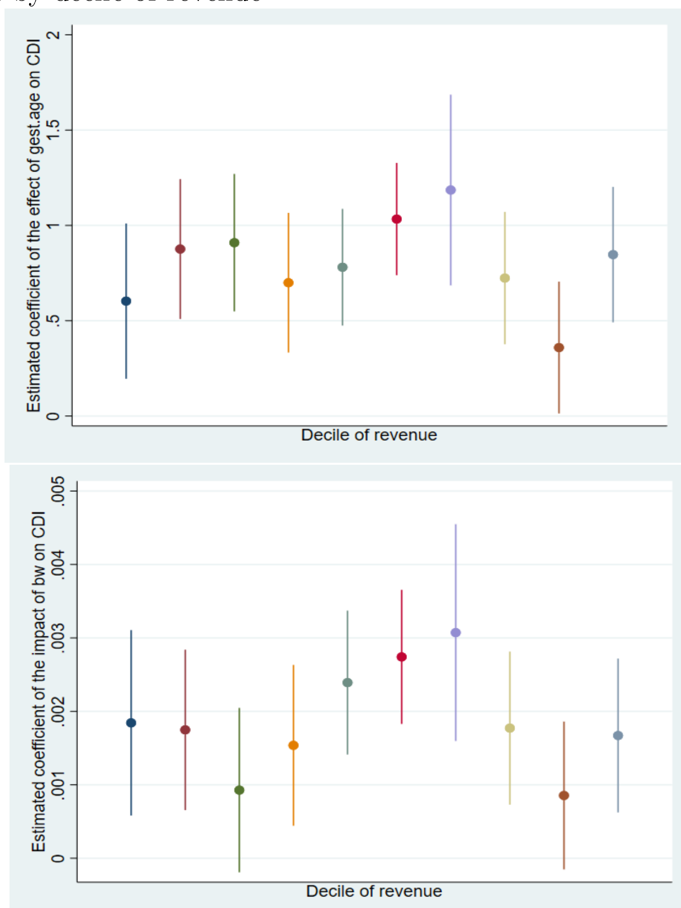
4.2 The impact of health on early child development with respect to socioeconomic characteristics

Given that we have found a causal effect of health at birth on child development and more particularly due to biological patterns, we now turn our attention to the impacts of health at birth on child development with respect to family's socioeconomic status. We ask whether there is evidence that the impacts of health at birth on child development are different according to parental income or education as proxies for socioeconomic status. In fact, Shiko and Eskil (2019) highlight the importance of exploring potential heterogeneous effect to offer insights into the mechanism behind the estimated birthweight effects. Figures 5 and 4 show the estimated coefficient of the impact of gestational age or birth weight on early child development by decile of revenue and level of education. Figure 4 highlights coefficients are slightly different with respect to decile of revenue although not significant. As shown in Figure 5, the impact of health at birth on child development is rather stable with respect to education. From these figures, it seems that poor neonatal health may not

[16] The impact of birth weight is significant in Column 4 but this result does not hold when adding control variables.

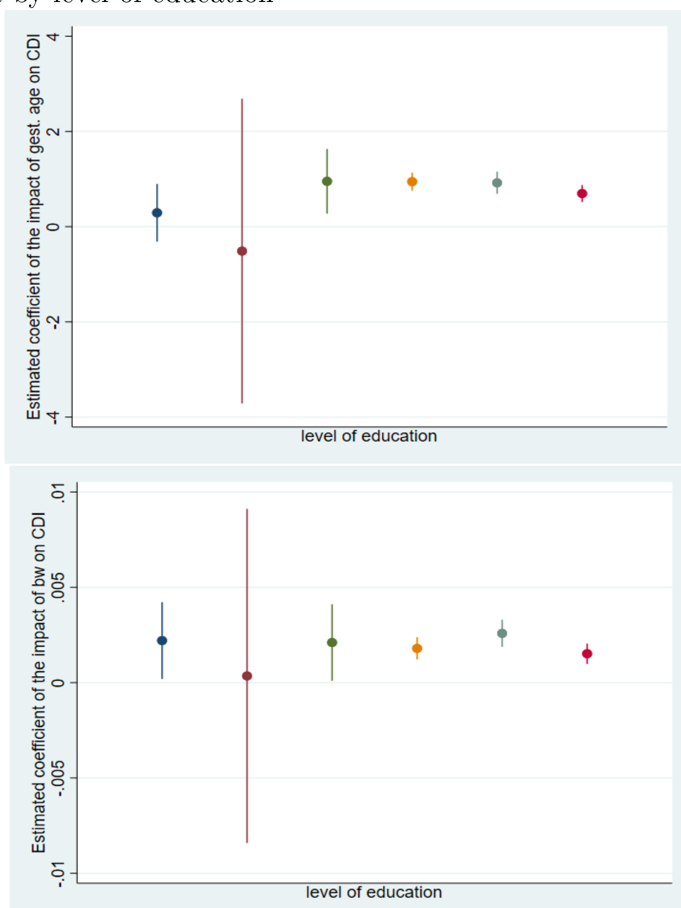
disproportionately affect children growing up in high socioeconomic status families compared to children in lower socioeconomic classes.

Figure 4: Estimated coefficient of the impact of gestational age and birth weight on early child development by decile of revenue



Note: The horizontal axis measures decile of revenue (REV_PART). The vertical axis shows the estimated coefficient of the impact of gestational age or birth weight on early child development for each decile.

Figure 5: Estimated coefficient of the impact of gestational age and birth weight on early child development by level of education



Note: The horizontal axis shows six level of education with respect to MEDUC variable. The vertical axis shows the estimated coefficient of the impact of gestational age or birth weight on early child development for each subsample of education.

To explore more deeply these potential sources of heterogeneity in the effect of birth health status on early development, we conduct a analysis in line with Currie and Stabile (2003) and Wei and Feeny (2019) by adding an interaction term in the regression. We thus include interaction of birth health and parental income and then of birth health and mother's education. Following theoretical predictions, all else equal, the effect of health at birth on child development for high income/educated household may be lower, larger or identical than for low income/educated households. All configurations are possible, depending on complementarity between inputs. Table 4 shows the estimated coefficient of the impact of gestational age or birth weight on early child development with interaction terms.

Columns 1 and 2 of Table 4 show the estimates of the impact of gestational age interacted with revenue using OLS and IV estimation, respectively. Columns 3 and 4 show the estimates of the impact of gestational age interacted with education. Columns 5 to 8 repeat the same exercise for birth weight. Analogous to Figures 4 and 5, we find once again no significant different effects of health at birth on child development with respect to the level of parental revenue or the level of mother's education.

These results indicate that the effects of health at birth are roughly the same for children from different socioeconomic classes. It does not exist inequalities in the impact of health at birth on child development in France. This conclusion is in line with the findings of Currie and Schwandt (Science 2016) for the US, that show inequality in mortality between rich and poor counties has strongly declined among infant. This suggests that, despite heterogeneous family's environment, there is an efficient treatment of health issue at early age that prevents an increase in socioeconomic inequality by the health channel.

5 Conclusion

We use an IV estimation approach based on PM10 pollution concentration exposure during pregnancy to identify the impact of health at birth on human capital in France. The data we use are unique in matching each child with its own pollution concentration exposure during mother pregnancy. The analysis is undertaken on the child level controlling for a wide set of child characteristics as well as seasonal and regional fixed effects. The results provide the first causal estimation of the impact of health at birth on early child development at the national level in France. The additional contribution here is to distinguish the effect of health at birth on human capital with respect to the level of revenue and education.

Preliminary estimation results indicate that an increase of 1 week gestational age at birth increases the average early child development at one year by 2.8 % in France. The analysis also provides evidence that this effect is only due to a direct biological effect. Further evidence that parental behavior does not play a role in this relationship come from the finding that health at birth has no effect on time investment. The results show no different impact according to socioeconomic factors suggesting an efficient treatment of health issues at very early age in France.

Future research should aim at a better understanding of the role of parental time investment in the effect of health at birth on human capital during childhood, in particular by studying child development after one year. Hence, future research could extend the analysis to test score to test whether the effect is different in later childhood. Such an analysis would also allow for a comparison of the effects in the long run.

Table 3: The impact of health on time investment

	Gestational age			Birth Weight		
	OLS	OLS	IV	OLS	OLS	IV
M00X_AGEGESTS	0.00616	-0.0953	-1.311			
	(0.122)	(0.153)	(2.363)			
M00X_POIENF				-0.000762**	-0.0000356	-0.00774
				(0.000368)	(0.000461)	(0.0128)
REV_PART	-0.000315	-0.000276	-0.000230	-0.000334*	-0.000286	-0.000182
	(0.000202)	(0.000277)	(0.000295)	(0.000202)	(0.000278)	(0.000295)
MEDUC	-0.270	-0.0170	-0.210	-0.251	-0.0115	-0.161
	(0.182)	(0.255)	(0.343)	(0.183)	(0.256)	(0.365)
RANG_ELFE		-0.994	-1.227*		-1.065*	-0.904
		(0.605)	(0.718)		(0.610)	(0.944)
SIB_1Y		-1.555**	-1.667**		-1.454**	-1.248
		(0.608)	(0.714)		(0.613)	(0.903)
M00M1_NAISGEM		-3.484**	-6.473		-3.224**	-9.105
		(1.390)	(5.675)		(1.385)	(9.642)
A01M_SEXEC1		1.015**	0.900*		0.971**	-0.224
		(0.417)	(0.493)		(0.424)	(1.785)
HOUSE_TYPE		2.078*	1.803		2.043*	1.666
		(1.119)	(1.140)		(1.122)	(1.125)
M00M3_GYMPREN		0.481*	0.717**		0.498**	0.723**
		(0.250)	(0.305)		(0.251)	(0.299)
M00M3_MENPEN		0.433***	0.417*		0.455***	0.386**
		(0.149)	(0.228)		(0.150)	(0.181)
M02M_TYPLOG		-0.712	-0.565		-0.703	-0.491
		(0.898)	(0.852)		(0.899)	(0.797)
M02M_ENFSANT		-0.0650	-0.345		-0.0515	-0.266
		(0.554)	(0.776)		(0.557)	(0.726)
A01M_ENFSANT		-0.971**	-1.233**		-0.953**	-1.309*
		(0.465)	(0.599)		(0.468)	(0.679)
A01M_PBSANTE		-2.916**	-3.314*		-3.008**	-3.679**
		(1.231)	(1.749)		(1.235)	(1.818)
COUPLEMATRI_M_1A		0.293**	0.319**		0.301**	0.276
		(0.124)	(0.143)		(0.125)	(0.178)
A01E_PONDNONREF		0.00198	0.00243		0.00239	0.00176
		(0.00546)	(0.00692)		(0.00548)	(0.00742)
URBAN		1.332**	1.291*		1.264**	1.025
		(0.528)	(0.700)		(0.531)	(0.644)
WORK_HOME_PREG		1.198	1.321		1.411	1.624
		(1.113)	(1.306)		(1.130)	(1.350)
M_AGE_2M		-0.0480	-0.0127		-0.0629	-0.0695
		(0.0564)	(0.0649)		(0.0570)	(0.0888)
MLENGHOME		-2.477*	-2.762*		-2.487*	-3.186*
		(1.473)	(1.473)		(1.487)	(1.685)
FLENGHOME		3.128**	3.488*		3.238**	3.166
		(1.552)	(1.949)		(1.561)	(2.141)
Wave FE	YES	YES	YES	YES	YES	YES
Regional FE	YES	YES	YES	YES	YES	YES
N	10394	7332	5899	10273	7255	5833
r2	0.0114	0.0380	0.0339	0.0118	0.0380	0.00515

Note: This table estimates the causal impact of gestational age and birth weight on time investment.
The dependent variable is the parental time investment variable. All estimations contain wave and regional fixed effect.
Standard errors (in parenthesis)
Statistical significance is denoted by: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 4: The impact of health on child development interacted with revenue or education

	Gestational age				Birth Weight			
	OLS	IV	OLS	IV	OLS	IV	OLS	IV
M00X_AGEGESTS_rev	0.0000562	-0.00328						
	(0.0000979)	(0.00265)						
M00X_AGEGESTS_meduc			-0.0300	18.69				
			(0.0761)	(40.69)				
M00X_AGEGESTS	0.561***	7.864	0.786**	-79.62				
	(0.204)	(5.769)	(0.327)	(175.1)				
M00X_POIENF_rev					0.000000147	-0.0000241		
					(0.000000268)	(0.0000219)		
M00X_POIENF_meduc							0.000143	0.0198
							(0.000233)	(0.0192)
M00X_POIENF					0.00137**	0.0585	0.00112	-0.0844
					(0.000568)	(0.0512)	(0.000993)	(0.0838)
REV_PART	-0.00229	0.129			-0.000583	0.0817		
	(0.00386)	(0.104)			(0.000941)	(0.0742)		
MEDUC			1.232	-733.2			-0.402	-65.72
			(2.992)	(1596.2)			(0.789)	(63.97)
RANG_ELFE	-0.354	-0.428	-0.318	-1.047	-0.383	-0.629	-0.351	-0.656
	(0.301)	(0.430)	(0.295)	(2.081)	(0.301)	(0.601)	(0.295)	(0.619)
SIB_1Y	0.465	0.587	0.498*	1.299	0.341	-0.215	0.375	1.161
	(0.296)	(0.414)	(0.289)	(2.163)	(0.295)	(0.909)	(0.289)	(0.841)
M00M1_NAISGEM	-2.137***	0.624	-2.067***	-8.933	-2.532***	8.436	-2.430***	-5.771*
	(0.805)	(2.753)	(0.795)	(13.86)	(0.807)	(10.26)	(0.796)	(3.234)
A01M_SEXEC1	1.497***	1.416***	1.511***	2.898	1.777***	3.072**	1.804***	1.414***
	(0.216)	(0.272)	(0.214)	(3.326)	(0.221)	(1.218)	(0.218)	(0.510)
HOUSE_TYPE	0.848	1.055	0.883*	0.355	0.959*	0.867	0.980*	0.998
	(0.536)	(0.650)	(0.533)	(1.074)	(0.532)	(0.838)	(0.529)	(0.806)
M00M3_GYMPREN	0.479***	0.318**	0.457***	0.314**	0.497***	0.0321	0.474***	0.419**
	(0.129)	(0.160)	(0.128)	(0.143)	(0.129)	(0.365)	(0.128)	(0.212)
M00M3_MENPEN	0.210***	0.0858	0.203***	0.200**	0.242***	0.180	0.238***	0.264*
	(0.0778)	(0.120)	(0.0774)	(0.0864)	(0.0783)	(0.157)	(0.0778)	(0.137)
M02M_TYPLOG	-0.156	-0.192	-0.164	-0.145	-0.207	-0.152	-0.205	-0.314
	(0.425)	(0.451)	(0.423)	(0.417)	(0.417)	(0.552)	(0.417)	(0.584)
M02M_ENFSANT	-0.491	-0.242	-0.487	-1.431	-0.511*	-0.114	-0.498*	-0.375
	(0.302)	(0.407)	(0.298)	(2.235)	(0.305)	(0.608)	(0.300)	(0.467)
A01M_ENFSANT	-1.093***	-0.801**	-1.106***	-0.914	-1.086***	-0.0540	-1.092***	-1.144**
	(0.293)	(0.374)	(0.291)	(1.073)	(0.293)	(0.965)	(0.291)	(0.454)
A01M_PBSANTE	1.460**	1.398**	1.411**	2.120	1.553**	1.735**	1.503**	1.575*
	(0.658)	(0.679)	(0.658)	(2.662)	(0.660)	(0.882)	(0.660)	(0.855)
COUPLEMATRI_M_1A	0.0767	0.159*	0.0895	-0.113	0.0957	0.489	0.110*	0.0259
	(0.0643)	(0.0922)	(0.0637)	(0.520)	(0.0650)	(0.347)	(0.0643)	(0.157)
A01E_PONDNONREF	0.00324	0.00232	0.00321	0.000208	0.00325	0.0115	0.00334	-0.00595
	(0.00291)	(0.00369)	(0.00293)	(0.0128)	(0.00294)	(0.00987)	(0.00297)	(0.0105)
URBAN	0.487*	0.259	0.469*	1.298	0.541**	0.400	0.524*	0.379
	(0.273)	(0.368)	(0.270)	(2.057)	(0.275)	(0.545)	(0.272)	(0.463)
WORK_HOME_PREG	0.943	0.368	0.860	4.043	0.994*	-0.141	0.935	2.041
	(0.594)	(0.953)	(0.585)	(7.080)	(0.601)	(1.638)	(0.591)	(1.347)
M_AGE_2M	-0.167***	-0.164***	-0.171***	-0.308	-0.157***	-0.143*	-0.165***	-0.274**
	(0.0304)	(0.0420)	(0.0300)	(0.287)	(0.0308)	(0.0782)	(0.0303)	(0.108)
MLENGHOME	-0.787	-1.457	-0.966	2.697	-0.632	-1.543	-0.838	-0.668
	(0.704)	(1.019)	(0.680)	(7.186)	(0.701)	(1.588)	(0.675)	(1.597)
FLENGHOME	-0.447	0.473	-0.372	-2.257	-0.318	1.084	-0.263	-2.155
	(0.755)	(1.222)	(0.748)	(5.044)	(0.760)	(2.025)	(0.753)	(2.372)
Wave FE	YES	YES	YES	YES	YES	YES	YES	YES
Regional FE	YES	YES	YES	YES	YES	YES	YES	YES
N	7332	5899	7471	6593	7255	5833	7391	5946
r2	0.0748	.	0.0751	.	0.0722	.	0.0731	.

Note: This table estimates the causal impact of gestational age and birth weight interacted with revenue and education on child cognitive development. The dependent variable is the Early child development. All estimations contain wave and regional fixed effect.
Note: Standard errors (in parenthesis)
Statistical significance is denoted by: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

6 Appendix

6.1 child development

To select questions of the ELFE cohort relevant to build the child development index, we use the methodology of Ireton (1992). Ireton (1992) provides a list of questions to appreciate the child development during the first year of life:

Table 5: Child development inventory based on the methodology of Ireton (1992)

Interested in his(her) image in a mirror.
Greets people with “Hi” or similar expression.
Feeds self a cookie.
Picks up a spoon by the handle.
Removes socks.
Chews food.
Drinks in a glass/cup.
Sits without help.
Stands steady without support.
Stands up without help.
Sidesteps around furniture or crib while holding on. Or walks.
Walks without help.
Picks up objects with one hand.
Holds two objects at the same time, one in each hand.
Uses two hands to pick up large objects.
Picks up small objects, using thumb and one finger.
Transfers objects from one hand to the other.
Builds a tower of two or more blocks.
Makes sounds like he(she) is talking in sentences. Or used to.
Jabbers.
Points to things.
Calls his(her) parents “Mama” or “Dada” or similar name.
Understands “No”; stops.
Responds to his(her) name.
Imitates some sounds that parents make. Or used to.
Comes when called.
Waves “bye-bye” or good-by.
Hands a toy to parents when asked.

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