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Locus of Control and Its Intergenerational Implications for Early Childhood Skill Formation

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ABSTRACT

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We propose a model in which parents have a subjective belief about the impact of their investment on the early skill formation of their children. This subjective belief is determined in part by locus of control (LOC), i.e., the extent to which individuals believe that their actions can influence future outcomes. Consistent with the theory, we show that maternal LOC measured at the 12th week of gestation strongly predicts early and late child cognitive and noncognitive outcomes. We also utilize the variation in maternal LOC to help improve the specification typically used in the estimation of skill production function parameters.

JEL Classification: J01, I31

Keywords: locus of control, parental investment, human capital accumulation, early skill formation, ALSPAC

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I. Introduction

Our understanding of what constitutes "skills" is changing. In recent years, there has been an increase in the number of studies written almost exclusively on the importance of noncognitive or *soft* skills, as opposed to cognitive or *hard* skills, in explaining educational or labor market success. The overall finding is clear: Measures of soft skills such as conscientiousness, extraversion, openness to experience, creativity, and self-esteem are important predictors of many successful human capital and labor market outcomes, including highest completed education level, productivity in the labor market, retention rates, and wages (see, e.g., Barrick & Mount, 1991; Salgado, 1997; Bowles et al., 2001; Heckman, 2006; Heineck, 2011).

Our study pays particular attention to one specific noncognitive skill that has recently been the focus of research in both labor and health economics: an individual's locus of control (LOC). LOC is a generalized attitude, belief, or expectancy regarding the nature of the causal relationship between an individual's behavior and its consequences (Rotter, 1966). According to psychologists, measures of LOC are designed to elicit individuals' beliefs about the extent to which they can control the events that affect them. Those with external LOC believe that events in their lives are outcomes of external factors (e.g., fate, luck, other people) and hence are beyond their control. Conversely, individuals with internal LOC generally believe that much of what happens in life stems from their own actions (Rotter, 1966; Gatz & Karel, 1993). Although there is generally a correlation between LOC and measures of ability,[1] the two are considered as separate concepts. High-ability individuals will typically invest more in their future because their marginal net return to investment is

[1] For example, the correlation between eighth grade LOC and eighth grade math ability is 0.286 in the National Educational Longitudinal Study (Coleman & DeLeire, 2003).

generally higher than that of low-ability individuals. Yet, irrespective of their ability, individuals with internal LOC will tend to invest more in their future than those with external LOC, simply because those with internal LOC *believe* that the returns to their investment will be guaranteed provided that they invest.[2]

One of the most important economic implications of LOC as a noncognitive skill is that it allows individuals to avoid immediate temptation in exchange for successful attainment of their long-term goals. With perhaps one exception,[3] the majority of empirical studies in this area have shown that individuals with internal LOC tend to invest more in their future through greater accumulations of human capital (Coleman & DeLeire, 2003) and health capital (Cobb-Clark et al., 2014). They also tend to search for a job more intensively when unemployed (Caliendo et al., forthcoming; McGee, forthcoming), and save more "for rainier days" than those with external LOC (Cobb-Clark et al., 2013).

Our study provides two main contributions to the literature. First, we argue that, in addition to the personal benefits, there is a significant—though so far overlooked—intergenerational benefit of internal LOC.[4] Using data from the Avon

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[2] According to the recent paper by McGee and McGee (2011), this condition holds only when there is a degree of uncertainty in the potential return to investment. For example, they find that there is virtually no difference in terms of search efforts between high- and low-LOC individuals in the laboratory when subjects know the true relationships between effort and offer.

[3] Using a different data set to Coleman and DeLeire (2003), Cebi (2007) does not find LOC to be a significant predictor of educational attainment once cognitive ability is controlled for; however, she finds LOC to be an important predictor of future wages.

[4] To the best of our knowledge, Cunha et al. (2013) is the only paper that has reported some preliminary evidence from the National Longitudinal Survey of Youth 1979 that children with extremely internal LOC mothers have, on average, higher levels of skill than children with extremely external LOC mothers.

Longitudinal Study of Parents and Children (ALSPAC) in the UK, we show that the rates of cognitive and emotional development are, on average, higher among children from internal LOC mothers than among children from external LOC mothers.[5] In an attempt to explain part of the mechanisms behind this reduced-form relationship, we show that mothers with internal LOC tend to believe in a more hands-on approach to parenting than mothers with external LOC. We also show that, by giving their children more exposure to stimulating activities inside and outside homes, the internal LOC mothers invest more in their children than the external LOC mothers, on average. The results are robust to controlling for pre-birth information, family background, and maternal education.

Our study's second contribution is to the early childhood development literature. In this branch of literature, researchers attempt to understand the role of parental characteristics and the early home environment in the production of both cognitive skills and noncognitive skills (see, e.g., Belsky & Eggebeen, 1991; Vandell & Ramanan, 1992; Parcel & Menaghan, 1994; Gregg et al., 2005; Bernal, 2008). Yet, according to Todd and Wolpin (2003), many empirical studies in this area suffer from several data limitations that prevent researchers from making causal inferences on their findings. The main reason for this is that most—if not all—early childhood input decisions are subject to choices made by parents. This would not necessarily pose a problem for researchers wanting to estimate a production function for child development if data on all relevant inputs as well as child endowments were observed. However, it does pose a problem when data on relevant inputs and endowments are missing.

[5] Taking the view that an individual household makes unitary decisions regarding child development in early years, we primarily focus in this paper on the effects originating from maternal LOC.

With longitudinal data, researchers can apply a first-difference (FD) model to correct for any permanent unobserved factors that normally bias the estimation of skill production function parameters, such as endowed mental capacity in children that do not change over time (Todd & Wolpin, 2003). Yet, the application of FD models often leave researchers with other statistical biases on the estimates. Examples of these are attenuation bias, which tends to be exacerbated in FD models (McKinnish, 2008), and a bias that arises from the unobserved natural development trend that is potentially correlated with both trends in parental inputs and trends in child outcomes.

We propose a new model specification that produces arguably more consistent estimates on the returns to parental investment. Our method consists of dividing the sample according to mother's LOC into *External*, *Neutral*, and *Internal*. By assuming that

- on average, children from different maternal LOC groups share the same unobserved natural development trend;
- measurement error in parental investment variables is, on average, the same across different maternal LOC groups;
- maternal investment is rising monotonically along the external–internal maternal LOC scale (i.e., at the extremes, the level of investment is highest among the most internalized LOC mothers and zero among the most externalized LOC mothers, with the *Neutral* group lying somewhere in between)

then a difference-in-differences (DD) model can be applied to correct for both attenuation bias and shared unobserved natural development trend bias. This allows us to obtain more consistent estimates of the effects of parental investment on child outcomes. Using this method, we find that the estimated effects of stimulating parenting on a child's cognitive development are generally larger in the DD specification than those in the FD specification, thus indicating that FD models may generally suffer from a severe attenuation bias that biases the estimates toward zero. Our overall findings continue to be robust under a difference-in-difference-in-differences (DDD) specification, in which group differences by maternal education are also taken into account in the estimation process.

The remainder of this paper is organized as follows. In section II, we sketch the theoretical framework that we use to motivate our empirical specifications. Section III outlines the data we use for the analysis, and section IV describes our empirical strategy. Our main results are summarized in section V. Section VI concludes.

II. Theoretical Framework

A. A Parental Investment Decision Model Without LOC

Assume that mothers have caring preferences for their children. More specifically, assume that a mother's value function in period $t, V_{P,t}$, consists of her own utility, $u_{P,t}$, and her child's utility, $u_{C,t}$, which is a function of the child's stock of human capital accumulation. The mother's value function can be written as

$$V_{P,t} = \sum_{t=S}^{T}[E(u_{P,t}) + E(u_{C,t})]\ \delta_{P,t}, \tag{1}$$

where $\delta_{P,t}$ is the mothers' discount rate. If we assume uncertainties in the outcome realization for mother and child, the two utility functions are respectively represented by their expected values, $E(u_{P,t})$ and $E(u_{C,t})$. We also assume equal weights across both utility functions at any given t, and that these weights are determined by the discount rate that varies over time.

If, for the sake of simplicity, we can assume that the child's utility is determined only by his or her stock of human capital, then there are two channels through which $E(u_{C,t})$ can be influenced. The first is through maternal investment, $I_{P,t}$, on the child's human capital, which the mother makes while accruing cost Z_t in the process. We assume that the mother's investment has a π_P probability of being successful at raising $u_{C,t}$. If we assume that the technology of skill formation is unknown to the mother, then the true value for π_P is also *a priori* unknown to her. This implies that the expected return to her investment, $E(u_{C,t})$, will depend on her beliefs about the efficacy of her investment (Cunha et al., 2013).

The second channel through which $E(u_{C,t})$ can be influenced is through investment from "Nature," which is costless to the mother and takes place independently of maternal investment. In an extreme case whereby the mother does not invest at all (i.e., setting $I_{P,t} = 0$), $E(u_{C,t})$ will depend entirely on Nature's investment, $I_{N,t}$. We assume that, similar to $I_{P,t}$, $I_{N,t}$ will have a π_N probability of being successful.

For simplicity, the production function of human capital is assumed (i) to be homogenous for all k types of investment and (ii) to automatically translate all investments into a new level of human capital stock, y_t, at the end of period *t*. We also assume that $f(.)$ is a linear function so that it is additively separable across types of investment. To clarify our argument, we summarize the net returns to each of the potential investment scenarios in tables 1A–1C.

In scenario A, in which the mother decides to invest in the child's human capital, the expected utility of the child conditional on both types of investment (i.e., maternal and from Nature) is

$$E(u_{C,t}^{A}) = [\pi_P \pi_N][f(I_{P,t}) + f(I_{N,t})] + [\pi_p(1-\pi_N)]f(I_{P,t}) + [\pi_N(1-\pi_P)]f(I_{N,t}) - Z_t, \quad (2a)$$

or

$$E(u_{C,t}^{A}) = \pi_P f(I_{P,t}) + \pi_N f(I_{N,t}) + (1-\pi_P - \pi_N) - Z_t. \quad (2b)$$

<u>In scenario B</u>, in which the mother decides **not** to invest in the child's human capital, the expected utility of the child conditional on investment from Nature is

$$E(u_{C,t}^{B}) = \pi_P \pi_N \, f(I_{N,t}) + \pi_N(1-\pi_P) \, f(I_{N,t}), \quad (3a)$$

Or

$$E(u_{C,t}^{B}) = \pi_N f(I_{N,t}). \quad (3b)$$

Equations (2b) and (3b) indicate that mothers will invest if, and only if, the expected net return to maternal investment is greater than the expected net return to no maternal investment. In other words,

$$I_{P,t} > 0 \; iff \; E(u_{C,t}^{A}) > E(u_{C,t}^{B}). \quad (4)$$

This is equivalent to

$$\pi_P f(I_{P,t}) > Z_t. \quad (5)$$

B. Adding LOC to the Parental Investment Decision Model

Recall that the expected return to the mother's investment depends on her beliefs about the efficacy of her investment (Cunha et al., 2013). Because LOC measures the belief about the nature of the causal relationship between an individual's behavior and its consequences (Rotter, 1966), we use it to capture maternal beliefs about the efficacy of investment and integrate it into our conceptual model of the maternal investment decision.

Let θ be a continuous measure of maternal LOC, which ranges from absolute external (0) to absolute internal ($+\infty$), where $\theta = 1$ indicates neutral LOC. We assume that θ affects mothers' perceptions of the values of π_P and, therefore, $E(u_{C,t})$. We also assume that a mother's assessment of the probability of her own investment being successful is a function of θ and some constant, $\bar{\pi}_P$, which is the objective probability of investment being successful, as follows:

$$\bar{\pi}_P = \pi_P^{\left(-\frac{1}{\theta}\right)}. \quad (6)$$

Equation (6) indicates that a mother with a value of θ greater than 1 (i.e., internal LOC) will overestimate the probability of investment being successful ($\pi_p > \bar{\pi}_P$), whereas a mother with a value of θ less than 1 (i.e., external LOC) will underestimate the true probability of success ($\pi_p < \bar{\pi}_P$). Figure 1 illustrates this relationship.

Thus, in the extreme cases, a mother with a value of θ equal to positive infinity believes that π_P is exactly equal to 1; that is, investing in the child's human capital will increase $E(u_{C,t})$ with absolute certainty. By contrast, a mother with a value of θ equal to 0 believes that π_P is equal to 0, which implies that investing in the child's human capital will certainly be futile. Hence, the abovementioned equation indicates that mothers with internalizing LOC will tend to expect higher returns to investment in the form of their child's utility for any given cost and hence will invest more than mothers with externalizing LOC across all time periods.

C. Implications of LOC for the Technology of Human Capital Formation

According to work by Heckman and colleagues, the technology of human capital formation is assumed to exhibit two key properties: (i) self-productivity and (ii) dynamic complementarity (Cunha & Heckman, 2007; Heckman et al., 2010). Self-productivity implies that the stock of human capital from the previous period is another key input to the production function, whereas dynamic complementarity implies that human capital accumulated in one period raises the marginal productivity of investment in subsequent periods. Taking these properties into account, we modify the skill production function $f(.)$ in section IIA to

$$y_t = g\left(y_{t-1}, \Sigma_k \ I_{k,t} \right), \quad (7)$$

where the linearity assumption on $g(.)$ is now relaxed and y_{t-1} is the stock of child human capital from the previous period. Self-productivity and dynamic complementarity imply that, in each period, differential levels of parental investment translate into different child development trends.

Although previous literature finds the sources of variation in maternal investment to be generally endogenous to the child's outcomes or correlated with the unobserved mother's background, we argue in section IIB that maternal LOC generates differential maternal investment levels through its implications on maternal beliefs about the efficacy of investment in child development. More explicitly, we can rewrite maternal investment as $I_{P,t}\,(\theta)$, where $\frac{\partial I_{P,t}\,(\theta)}{\partial \theta} > 0$. We assume that maternal LOC, unlike other sources of variation in maternal investment decisions, is *ceteris paribus* uncorrelated with child endowments that simultaneously influence child outcomes.[6]

We introduce this variation in maternal investment level as an additional feature of Todd and Wolpin's (2003) FD specification. More specifically, we estimate the returns to parental investment in early childhood human capital by using a DD estimator, which thus enables us to obtain input parameters that are arguably more

[6] A recent study by Cobb-Clark and Schurer (2013) has also shown LOC to be relatively time-invariant and uncorrelated with various socio-demographic statuses and life events in adulthood.

consistently estimated than if only a FD estimator was used to estimate the model. The relevant empirical strategy is described in more detail in section VB.

III. Data

A. The ALSPAC Cohort

ALSPAC[7] is a near-census English cohort survey designed to study the effect of environmental, genetic, and socio-economic influences on health and development outcomes of children. ALSPAC recruited pregnant women residing in the Avon area with expected delivery dates between April 1, 1991, and December 31, 1992. A total of 14,541 pregnancies (80–90% of all pregnancies in the catchment area) resulted in a sample of 13,971 children at age 12 months. The sample is representative of the national population of mothers with infants less than 12 months old (Boyd et al., 2013) and contains multiple high-frequency reported measures on cognitive and socio-emotional skills in infancy as well as a very rich set of parental investment measures and parental characteristics collected from the prenatal period onward. At the ages of 7, 8, and 9 years, the ALSPAC cohort underwent physical, psychometric, and psychological tests administered in a clinical setting. Administrative data from the National Pupil Database has been matched to the ALSPAC children, containing school identifiers and results of national Key Stage school tests for all children attending public schools in the four Local Educational Authorities[8] that cover the Avon area. As with any large cohort survey, the usual attrition due to loss in follow-

[7] Please note that the study website contains details of all the data that is available through a fully searchable data dictionary (http://www.bris.ac.uk/alspac/researchers/data-access/data-dictionary/). Ethical approval for the study was obtained from the ALSPAC Ethics and Law Committee and the Local Research Ethics Committees.

[8] These Local Educational Authorities are Bristol, South Gloucestershire, North Somerset, and Bath and North East Somerset.

up applies in the later waves. Moreover, the participated mothers did not always answer every single question in every part of the questionnaires, which means that the sample size may vary across different regression equations. Our strategy is to conduct all of our analyses using only complete cases.

B. Measures of Early Childhood and Adolescent Outcomes

We based our measures of early childhood outcomes on language and socio-emotional skill development. We constructed a panel of these two dimensions of early skill formation. Language development is a key part of early cognitive development and facilitates all other dimensions of early skill formation. Moreover, language skills at school-entry age predict educational attainment at later ages (Duncan et al., 2007). We measured both receptive and expressive language development by using the MacArthur Communicative Development Inventory, a mother-assessed questionnaire on early language development. Mothers were asked to report whether their child could understand (receptive) and use (expressive) listed vocabulary items (Law & Roy, 2008).

Early socio-emotional skill development was mostly captured using mothers' responses to questions on child temperament. We elicited child's temperament by using 20 questions on the Emotionality, Activity, and Sociability (EAS) Temperament scale (Buss & Plomin, 1984) and used them to construct measures of early socio-emotional skills by means of iterated exploratory factor analysis. The EAS Temperament questions were included in three waves (38, 57, and 69 months). In each wave, we retain two factors with eigenvalue greater than 2. The factors were extracted following the criteria outlined by Gorsuch (1983), which have also been used by Heckman et al. (2013) to construct measures of noncognitive skills. Under these criteria,[9] two factors have been extracted.[10] We interpret the first factor as extraversion, reflecting the degree to which a child is generally happy and active and enjoys seeking stimulation. The second factor is interpreted as a measure of emotional instability (e.g., crying, temper tantrums).

We based our outcomes in adolescence on the child's educational attainments and emotional health at age 16 years. We used the average total score of the General Certificate of Secondary Education (GCSE) test, which is a national test generally taken in the UK in a number of subjects at ages 14–16 years, as a measure of educational attainment. Emotional health was measured using the Short Mood and Feelings Questionnaire (SMFQ) reported by the mothers. This assessment instrument is typically used to capture an adolescent's underlying continuum of severity of depressive symptoms (Sharp et al., 2006). Mothers assessed their adolescent's emotional health by means of 12 questions on a three-point scale (true, sometimes true, not true). We constructed the SMFQ score as an aggregate of these 12 questions, where higher values represent better emotional health.

C. Measures of Locus of Control

Maternal and paternal LOC were derived from the Adult Nowicki and Strickland Internal–External questionnaire (Nowicki & Duke, 1974a), which had been reported by parents at the 12th week of gestation of the ALSPAC children.[11] Responses to the

[9] The exploratory factor analysis identifies blocks of measures that are strongly correlated within each block (i.e., satisfy convergent validity) but are weakly correlated between blocks (i.e., satisfy discriminant validation). Measures that load on multiple factors are discarded from the analysis. We impose (Quartimin) Oblique rotation of factor loadings to allow for correlation between the factors.

[10] See appendix A.

[11] For the list of questions, see appendix B.

12 self-completed questions were then aggregated to create maternal and paternal LOC scores, with higher values representing more external LOC. We also constructed a measure of child's LOC at 9 years old based on a shortened version of the Nowicki and Strickland scale for preschool and primary children (Nowicki & Duke, 1974b).[12] For our analysis, we grouped mothers, their partners, and their children by their relative percentile ranking on their LOC scores. Within each group, we classified those in the top quartile as *External LOC* and those in the bottom quartile as *Internal LOC*. The *Neutral LOC* then consists of those whose ranks were between 25th and 75th percentiles.

D. Measures of Parental Investment

Information on parental investment comes from (i) self-reported attitudes toward parenting and (ii) self-reported parental time-use data. When the cohort child was 8 months old, both parents were asked questions on their attitudes toward parenting. To construct measures of time inputs, we relied on the self-reported parental activities with the child. The data contains information on the number of times in a given period that mothers and their partners individually engage in an activity with their child. First, we performed exploratory factor analysis as described previously in Section III.B to determine the dimensionality of these parental time investment inputs. For maternal time input across all time periods, factor analysis produces three dimensions: (i) basic care, (ii) playing with the child, and (iii) cognitive stimulation activities. For partners, factor analysis produces two dimensions: (i) basic care and (ii) cognitive stimulation activities. For outdoor activities in which children engage with their

[12] For the list of questions, see appendix C.

parents, factor analysis produces two dimensions: (i) active and (ii) passive outside activities.

After conducting the exploratory factor analysis, we obtained statistical guidelines on how each of these parental investment variables should be aggregated. Instead of extracting the factors, we decided to reduce the dimensionalities of our inputs while keeping our new index variables tractable by calculating an average index for each type of parental activities. For each input dimension, we aggregated all comprising variables by calculating an un-weighted index. In total, we obtained the maximum of eight indices of parental time investment in each period. These are (i) maternal basic care activity, (ii) maternal playing with the child activity, (iii) maternal cognitive stimulation activity, (iv) paternal basic care activity, (v) paternal playing with the child activity, (vi) paternal cognitive stimulation activity, (vii) active outside activity, and (viii) passive outside activity.[13]

IV. Empirical Strategy

Our empirical strategy comprises two distinct parts. The first part describes an econometric model, which we use to estimate the reduced-form relationships between maternal LOC and various child outcomes, as well as maternal attitudes toward parenting and actual investment levels. The second part describes how we use the DD and DDD specifications, which incorporate the variations in maternal investment behaviors driven by maternal LOC, to obtain a more consistent estimate of the returns to parental investment.

[13] For details of each variable contained in each index, and the panel structure of the indices, see appendix D.

A. Using Maternal LOC to Predict Child Outcomes and Parental Investment

One testable hypothesis is that the children of internal LOC mothers will generally exhibit higher levels of development than children of external LOC mothers. To test this, we estimate the following reduced-form regression equation:

$$Y_{i,t} = \alpha_1 + \alpha_2 LOC_{i,t} + X'_{i,t}\rho + \epsilon_{i,t}, \qquad (8)$$

where $Y_{i,t}$ denotes child *i*'s outcome at time *t* as reported by the mother, which includes either cognitive and noncognitive outcome at various stages of child development; $LOC_{i,t=0}$ is a set of dummies representing the level of maternal LOC at 12th week of gestation (e.g., *Neutral* and *Internal*); $X'_{i,t}$ is a vector of control variables that includes child's characteristics at birth, maternal education, maternal mental health, and child's own LOC measured at age 9 years; and $\epsilon_{i,t}$ is the error term. Here, the hypotheses are that $\alpha_2 > 0$ and $\alpha_{2,Internal} > \alpha_{2,Neutral}$.

To test for the possible mechanisms that link maternal LOC to child outcomes, we estimate a similar reduced-form equation:

$$I_{i,t} = \eta_1 + \eta_2 LOC_i + X'_{i,t}\kappa + \varepsilon_{i,t}, \qquad (9)$$

where $I_{i,t}$ is either a measure of mother's attitudes toward parenting or the actual level of maternal (or paternal) time investment in child *i* at time *t*. The hypothesis is that the average level of investment at any given *t* will be higher for internal LOC parents than for external LOC parents. In other words, we test whether $\eta_2 > 0$ and $\eta_{2,Internal} > \eta_{2,Neutral}$.

B. Using Maternal LOC to Estimate the Returns to Parental Investment in Early Child Development

Consider the following regression equation:

$$Y_{i,t} = I'_{i,t}\beta + X'_{i,t}\rho + \varsigma_{i,t}. \qquad (10)$$

Running ordinary least-squares (OLS) on equation (10) will produce a vector of unbiased estimates of β_2 if, and only if, parental investment variables are orthogonal to the error term $\epsilon_{i,t}$. However, this assumption is unlikely to hold. This is because parental inputs are potentially endogenous to child development, and we simply cannot include in the list of our control variables, $X'_{i,t}$, comprehensive measures of innate ability of parents (and child) and the history of all inputs that go into the production function.

To account for individual unobserved components in equation (10), let us first decompose the error term $\varsigma_{i,t}$ into the individual-specific effect component, ω_i, and time-varying component, $\nu_{i,t}$, as follows:

$$\varsigma_{i,t} = \omega_i + \nu_{i,t}. \qquad (11)$$

Given the longitudinal nature of the ALSPAC data, we can deal with the individual-specific effect via first-differencing.[14]

$$Y_{i,t} - Y_{i,t-1} = \left(I_{i,t} - I_{i,t-1}\right)'\beta + \left(X_{i,t} - X_{i,t-1}\right)'\rho + \left(\nu_{i,t} - \nu_{i,t-1}\right). \quad (12)$$

Assuming that $\left(I_{i,t} - I_{i,t-1}\right)'$ is orthogonal to $\left(\nu_{i,t} - \nu_{i,t-1}\right)$, then equation (12) should produce consistent estimates on β.

Although the FD model can be used effectively to eliminate ω_i, it introduces more random noises into our regression model, which bias our estimates toward zero (Wooldridge, 2010). This increase in the attenuation bias following an application of the FD model is likely to be more prevalent in the ALSPAC data set, because

[14] Depending on the richness and the nature of the data set available to researchers, Todd and Wolpin (2003, 2007) propose different estimation strategies to deal with the omitted variables problems and discuss the assumptions under which each of these estimators identifies the production function. Examples of these models are OLS, fixed effects (within-family and within-child), and value added.

measures of parental investment are likely to vary, by nature, across the various stages of child development.

Moreover, the FD estimates are subject to omitted time-varying variables bias if $(\nu_{i,t} - \nu_{i,t-1})$ is not independently and identically distributed (i.i.d). All children may, for example, share the same unobserved natural development trend, which may also happen to be positively correlated with trends in parental investment decisions, thus imposing an upward bias on the FD estimates. Other examples of important time-varying variables that we are unable to control for in our parental investment decision regression equations are parents' work hours and wages. It is also likely that parental investment choice to reinforce or compensate observed child outcomes is not directly observed in the data. Given that both positive biases and negative biases are involved, the direction of the bias is unclear on *a priori* grounds.[15]

We propose a model specification that attempts to solve the omitted time-varying variables bias mentioned above. More specifically, we exploit the fact that, among comparable mothers in the population, different maternal LOC leads to differential child investment behaviors. Our empirical specification uses this unique cross-sectional variation to help identify a more consistent estimate of β. Our identification strategy is as follows.

Recall our earlier conceptual framework in which human capital development is driven by two main sources of inputs: explicit investment activities by the parents and the natural development of the child. We assume that, among mothers with

[15] These problems are empirically challenging and not easy to solve using instrumental variable techniques. This is because, as highlighted by Todd and Wolpin (2003), potential instruments are likely to be correlated with other omitted inputs reflecting investment decisions and the endogenous regressors (or the included inputs) of interest.

different LOC, the accumulation of human capital for children from highly internal LOC mothers is determined by both these input sources. By contrast, children from highly external LOC mothers are assumed to accumulate their human capital only through their natural development; that is, parental inputs are set to zero. Our strategy thus involves further categorizing children from highly external LOC parents as our *control* group and those from highly internal LOC parents as our *treatment* group. This categorization allows us to introduce an extended specification from the FD model by adding the variation in maternal investment behavior derived from maternal LOC as an additional difference in the model specification.

In our proposed DD model, there are two periods. In the first period, the investment decision is made, and in the second period, the outcomes are realized and observed. Because the child's production function is unobserved to mothers, there is uncertainty about the returns to investment in the first period. Thus, any variation in maternal investment levels observed in the first period is assumed to have come primarily from initial differences in maternal beliefs about the return to investment effort determined by their LOC.[16] Assuming that (i) all children share the same development trend and (ii) measurement error in parental investment variables is, on average, the same across different maternal LOC groups, then we can correct for both the unobservable natural development trend bias and the attenuation bias in our estimation of the return to parental investment decisions, simply by taking the between-group differences (control versus treatment) with respect to within-person changes in parental investment and child outcomes.

[16] We also present supporting evidence in appendix E that the children across these three groups are comparable in terms of their ability in infancy.

To illustrate, we sub-divide our sample into three groups of maternal LOC—*External* (top quartile), *Neutral* (middle quartiles), and *Internal* (bottom quartile)—and estimate the following DD specification:

$$Y_{i,t,L} = I'_{t,L}\beta + \delta_1 LOC_L + \delta_2 T_t + X'_{t,L}\rho + \epsilon_{t,L}, \qquad (13)$$

where $Y_{i,t,L}$ is a level of human capital, measured at time *t*, of a child *i* whose mother has *L*-type LOC; $I'_{t,L}$ is a vector of parental investments; LOC_L is a set of dummies for each type of maternal LOC (*Neutral*, *Internal*); T_t is the time dummy (0,1); $X_{t,L}$ is a vector of the child's birth traits and the time-varying parental characteristics, including parental health-related behaviors, maternal mental health, and maternal physical health; and $\epsilon_{t,L}$ is the error term, where we assume that $E(\epsilon_{t,L}|t,L) = 0$.

The key identifying assumption here is that, in the absence of treatment, both the attenuation bias and the natural development trends are the same across maternal LOC groups, on average. Hence, under this specification, the DD is given by

$$= \Delta E[Y_{Internal}] - \Delta E[Y_{External}]$$

$$= \beta(\Delta\square[I_{Internal}] - \Delta E[I_{External}]). \qquad (14)$$

The DD specification thus enables us to obtain the unbiased estimate of β, which is the average return to maternal investment on child development from a one-unit increase in input between periods 0 and 1.

However, it may be the case that the unobserved natural development trend of a child is not the same across all children, but is a function of maternal socio-economic backgrounds. Hence, the above DD specification may violate the common-trend assumption if differences in the trends by maternal socio-economic background are not controlled for in the estimation process. To mitigate this issue, we introduce maternal education ("*High School Graduates*" and "*High School Dropouts*") as a third variation. This is an attempt to capture any differences in the development trends caused by differences in maternal socio-economic backgrounds, particularly the natural development of the child's human capital, which may have been caused by different technologies of skill formation across households with different abilities. The DDD specification can be written as follows:

$$Y_{t,L} = I'_{t,L,E}\beta + \tau_1(LOC_L * T_t) + \tau_2(T_t * EDU_E) + \tau_3(LOC_L * EDU_E) + X'_{t,L,E}\rho + \vartheta_{t,L,E}, \quad (15)$$

where Edu_E is a dummy variable representing whether the mother has completed at least a high-school qualification (A level). All of our models are estimated using OLS with robust standard errors. Note also that we focus our FD, DD, and DDD analyses on only early child outcomes, which is where child development is most likely to have been influenced entirely by the parents and less so by the school and peers.

V. Results

A. Reduced-form Child Outcome and Parental Investment Equations

Focusing on maternal LOC as the explanatory variable of interest, tables 2A and 2B respectively present the reduced-form OLS estimates with adolescent outcomes measured at age 16 years and early outcomes at ages 1, 2, and 3 years. The outcomes at age 16 years in table 2A consist of cognitive (i.e., the average total GCSE scores) and noncognitive (i.e., the SMFQ scores) aspects of child outcomes. Early child outcomes reported in table 2B consist of (i) the MacArthur Receptive Score (MRS), (ii) the MacArthur Expressive Score (MES), and (iii) the EAS Temperament score (EASTS). All outcomes are standardized to have a mean of 0 and a standard deviation of 1.

Can we use maternal LOC measured at the 12th week of gestation to predict child outcomes at age 16 years? To answer this question, let us first refer to column 1 in panel A of table 2A. In a basic specification without any control variables other than the child's gender, we can see that both *Neutral* and *Internal* dummies of maternal LOC enter the GCSE regression equation in a positive and statistically significant manner. The estimated relationship between maternal LOC and the total GCSE score is also monotonic: The coefficients on "*Maternal LOC: Neutral*" and "*Maternal LOC: Internal*" are 0.486 and 0.778, respectively.

Controlling for child's characteristics at birth (i.e., birth weight, weeks of gestation, head circumference at birth, crown–heel length, number of siblings 0 to 15 years old, number of siblings 16 to 18 years old, mother's age at birth), his or her life events between ages 9 and 11 years (e.g., death within the family, family illness, parents' relationship, mother's pregnancy, family income and employment situations, financial difficulties, and housing situations), and his or her prior attainment (i.e., the Key Stage 2 score and IQ score at 9 years old) in column 2 of panel A reduces the size of the coefficients on maternal LOC by approximately two-thirds of the original coefficients. However, both coefficients continue to be positive, sizeable, and statistically well determined.

Adding the child's own LOC (reported at age 9 years) in column 3's specification does little to change the coefficients on maternal LOC, thus indicating that the effect of maternal LOC on child's educational attainment may not have worked through its impacts on the child's LOC alone. Moreover, consistent with Coleman and DeLeire (2003), there is significant evidence that internal LOC children perform significantly better at GCSE examinations than the relatively external LOC children; the coefficient on "*Child LOC: Internal*" is positive at 0.067 and statistically significant at the 5% level.

A proxy for mother's ability in the form of maternal education (i.e., completing high school or higher) is added as an additional control in column 4. Although maternal education enters the child's educational attainment regression positively and statistically significantly, including it in the specification changes the coefficients on maternal LOC only slightly. In this full specification, children with internal LOC mothers score around 17% higher in the standardized GCSE score than children with external LOC mothers, and children with neutral LOC mothers score around 11% higher, on average.

The pattern is not as robust when we focus on SMFQ as the outcome. In the most parsimonious form of specification (i.e., column 5), we can see that both maternal LOC dummies are positively and statistically significantly correlated with the SMFQ scores, although we cannot reject the null hypothesis that the sizes of the two coefficients on maternal LOC are the same. By sequentially adding background controls, we reduce the magnitude of these coefficients from around 0.20 to 0.15, which is sufficient to render their statistical significance from being significant at the 5% level to being marginally significant at the 10% level.

Turning to early child outcome estimates in table 2B, we can see that maternal LOC are good predictors of MRS at ages 1, 2, and 3 years. Children with internal LOC mothers tend to exhibit higher MRS than children with neutral LOC mothers and children with external LOC mothers. The findings in the MES and the EASTS regressions are mixed. For example, although the coefficients on both maternal LOC dummies are positive and statistically significant at conventional levels in the MES regression equations at ages 1 and 3 years, having an internal LOC mother appears to be worse for the child in terms of MES at age 2 years. Moreover, having an internal LOC mother is associated with higher EASTS only at ages 4 and 5 years but not at age 1 year. Nonetheless, our evidence seems to point toward a generally better outcome for children with internal LOC mothers than for children with external LOC mothers.

Why do children with internal LOC mothers tend to perform better, on average, at these different cognitive and noncognitive outcomes at different stages of their lives? There are many potential explanations for this, including the omission from the model of important variables that correlate with both child outcomes and maternal LOC. However, a more preferable explanation is that internal LOC mothers generally believe that much of what happens in the child's life stems from the mother's actions and not from luck. This implies that internal LOC mothers will tend to put in greater efforts than external LOC mothers at cognitively stimulating their child with activities that they *believe* to be more helpful for the child in the future. This may include reading to their child and teaching their child how to read.

We first test this hypothesis using maternal and paternal attitudes toward parenting as outcome variables, and we report the estimates on maternal LOC in tables 3A–3C. Looking across the columns in all three tables, we can see that internal LOC mothers are significantly more likely than external LOC mothers to believe that babies need stimulation to develop, that parents should adapt their life for babies, that babies should not fit into parents' routines, that babies' development should not be natural, and that it is important to talk to babies of all ages. The estimates are statistically robust and remarkably consistent in the regression equations where the mother was asked the questions at 32 weeks of gestation (table 3A) and when the child was 8 months old (table 3B). There is also some evidence of a positive relationship between maternal LOC and the father's belief in being active in the child's upbringing, even when paternal LOC is held constant (table 3C). Surprisingly, paternal LOC does not seem to be robustly correlated with father's attitudes toward parenting, when holding maternal LOC and both parents' education constant.

Are the gaps in attitudes toward parenting between internal and external LOC mothers also reflected in their actual investment decisions? Table 4A shows that this is largely the case. Using maternal LOC to predict an index of maternal investment in providing cognitive stimulation activities for her child at ages 1, 4, and 5 years, we can see that the coefficients on "*Maternal Neutral LOC*" and "*Maternal Internal LOC*" are both positive and statistically significant at the 1% level. Within the same regression, the coefficient on "*Maternal Internal LOC*" is also noticeably more positive than the coefficient on "*Maternal Neutral LOC*," thus indicating that the level of investment is monotonically increasing with being more internal in LOC. The results are also robust to controlling for maternal education.

We can break down the parental time investment measure into various disaggregated types of investment, including active outside activity (e.g., take to interesting places, take to library), passive outside activity (e.g., take to a shop), cognitive stimulation activity (e.g., read to the child), playing with the child activity (e.g., physical play with the child), and basic caring for the child (e.g., bath, make meals).[17] By re-estimating equation (9) on these disaggregated investment variables at two different stages of child development (ages 0–1 years and 4–5 years), we observe maternal LOC to strongly predict less time of either parent engaging the child in passive outside activities, more active outside activities for the child by either parent only at ages 0–1 years, more maternal cognitive stimulation activities at both stages, more maternal time of playing with the child at both stages, and more maternal basic care to the child only at ages 4–5 years. Maternal LOC also strongly predicts higher

[17] For the full detail, see appendix D.

levels of paternal cognitive stimulation at ages 4–5 years, paternal playing with the child at both stages, and paternal basic case for the child at both stages. These results are also robust to controlling for paternal LOC, which also strongly predicts investment in paternal investment equations, and father's education.[18]

Table 4B moves on to test whether the previous estimates on maternal LOC will remain statistically robust in regressions where the lagged-dependent variable is included as an additional control variable. This is a basic test for the presence of a dynamic process in how maternal LOC influences the level of investment over time. By including prior investment level as an additional control variable, we can see that there is a significant increase in the level of "*Active Outside*" index by either parent between ages 1.5 and 3.5 years among the internal LOC mothers compared with that among the external LOC mothers. Conditioning on passive outside activities (e.g., taking child shopping) at an earlier age, the maternal LOC dummies continue to enter the passive outside activities at a later age in regression equations in a negative, sizeable, and statistically significant manner. A similar pattern is also observed for maternal cognitive stimulation activities at age 3.5 years, and paternal cognitive stimulation activities at ages 3.5 and 5 years.

In summary, our results provide strong evidence that maternal LOC is an important predictor of many important indicators of successes in childhood, especially the indicators that represent cognitive development. Therefore, part of this observed relationship is potentially explained by the well-determined correlations between maternal LOC and the attitudes toward parenting by both the mother and the father, which is also reflected in the higher levels of maternal and paternal investment that are observed among the internal LOC mothers. Finally, there is some evidence from

[18] Because of limited space, our breakdown estimates can be found in appendices F and G.

the lagged-dependent model that the internal LOC mothers will continue to put in incrementally more investment at various stages of child development than the external LOC mothers. This last finding is important for the type of analysis we wish to conduct in the next section because it indicates that maternal LOC, which is relatively stable over the life course, has a dynamic influence on the level of parental investment at various stages of child development.

B. Using Maternal LOC to Estimate the Effects of Parental Investment on Child Outcomes

To illustrate how input parameters in a child production function can be estimated, the first two columns of tables 5A and 5B follow Todd and Wolpin's (2003, 2007) empirical strategy and estimate, for different development periods, FD regression equations, in which changes in early communication skills (MacArthur: Receptive and Expressive) are the outcome variables, and changes in different parental time inputs are included on the right-hand side as parental investment variables.

What we find is that a unit change in the index of maternal stimulating activities correlates positively and statistically significantly with both measures of early communication skills in the child's first two years. The magnitude of the estimated relationship is small: A 1 standard deviation increase in the maternal stimulating activities index predicts a standard deviation increase of around 0.04–0.05 in child early communication skills between ages 1 and 2 years. The estimated coefficient on maternal stimulating activities index is positive albeit statistically insignificant in regressions where changes in the MacArthur's communication skills were measured between ages 2 and 3 years.

There is also evidence of other stimulating activities being positively linked with improvements in child early communication skills. For example, changes in paternal cognitive stimulation activity index have a moderately positive relationship with changes in the expressive communication skills in both periods of changes (i.e., ages 1–2 and 2–3 years). The positive link between paternal cognitive stimulation activity index and receptive communication skills is statistically significant only when the outcome variable is the change in early communication skills between ages 2 and 3 years. There is also some evidence that an increase in the stimulating child outside index is statistically significantly linked with an increase in receptive communication skills from ages 2 to 3 years. Nevertheless, the estimated magnitudes of these relationships are mostly small; that is, none of the estimated standardized coefficients on stimulating activities index is larger than 0.05 (or 5% of the standard deviation).

Other FD estimates also produce results that are more difficult to predict. For example, we find both maternal and paternal playing with the child indices to be mainly statistically insignificantly related to changes in early communication skills in the first two years, when other factors are held constant.

The next three columns of tables 5A and 5B report estimates obtained from running equation (13). The DD estimates generally produce coefficients on the stimulating activities index that are more positive than those obtained in the FD model. For example, both of the estimated DD coefficients on the maternal cognitive stimulation activity index in receptive and expressive communication skills between ages 1 and 2 years are three times larger than the FD estimates; a 1 standard deviation increase in the maternal cognitive stimulation index is now associated with 14% and 17% increases in the standardized receptive and expressive communication skills, respectively. Additionally, we find that the estimated DD coefficients on the paternal cognitive stimulation activity index and on the active outside activity index are noticeably larger than their FD counterparts in both sets of receptive and expressive communication skills regression equations, thus indicating that there may have been a significant attenuation bias in the FD regression model that biased most—if not all—FD estimates on the parental cognitive stimulating activities index toward zero.

Looking across columns in both tables, we can see that the differences between the FD and DD estimates are not as clear-cut for most of the other remaining input variables as for those obtained for the stimulating activities variables. For example, there is virtually no difference between the FD and DD coefficients on the mother's playing with the child index in the receptive communication skills regressions; it appears that changes in maternal playing with the child simply do not correlate positively and statistically significantly with changes in early communication skills, irrespective of whether or not we can correct for the attenuation bias and take natural development trends into account in our estimation process.

Almost the same estimates as the DD specification are obtained in the DDD regression equations presented in the last three columns of tables 5A and 5B. This indicates that it makes virtually no difference whether or not we allow for the additional between-group differences by maternal education in the estimation process. The overall conclusion is the same: FD models appear to underestimate the effects of cognitive stimulation activities on child development, perhaps because of the severe attenuation bias that tends to be exacerbated following the first-differencing process.

VI. Conclusions

This paper provides the first empirical evidence on the intergenerational benefits of LOC. Using extremely rich cohort data, we show that LOC of the mother measured at the 12th week of gestation significantly predicts educational attainment and emotional health of the child at age 16 years. The results are robust to controlling for a battery of maternal characteristics at the time of birth, as well as both parents' education and the child's own LOC. We also provide evidence of a positive and statistically significant link between maternal LOC and early child outcomes, which include measures of language development skills and socio-emotional skills.

We attribute our findings to the evidence that mothers with internal LOC are more likely to believe in the importance of an active parenting style and, as a result, tend to engage their children in more cognitive stimulating activities (e.g., reading and singing) than mothers with external LOC. This is consistent with the conceptual framework that incorporates an individual's subjective beliefs about the efficacy of investment in their children's early skill formation, whereby subjective beliefs are determined by the individual's LOC—that is, the extent to which individuals believe that their own actions affect future outcomes. It is also consistent with the evidence provided by recent studies in the economics literature of an important link between individual's LOC and various investment decisions, including the individual's decision to invest in higher education, savings, job seeking, and maintaining a healthy lifestyle (e.g., Coleman & DeLeire, 2003; Cobb-Clark et al., 2014; Caliendo et al., forthcoming; McGee, forthcoming).

Our study also introduces LOC as a potentially important tool for researchers to improve the quality of their estimates in their search to identify the production function parameters (Todd & Wolpin, 2003). By explicitly allowing for first-differences and between-group differences with respect to maternal LOC, we are able to correct not only for the unobserved heterogeneity bias, but also for a large part of the attenuation bias and the unobserved natural development trend bias. Based on our estimates on the effects of maternal cognitive stimulating activities on early child language development skills, we conclude that Todd and Wolpin's (2003) recommended use of a FD model to account for the unobserved heterogeneity bias whenever data permits may produce estimates of the production function parameters that are severely underestimated because of the attenuation bias.

More generally, these results advance our understanding of the role that an individual's LOC plays in the parental decision-making process. Nonetheless, our study is not without shortcomings. For example, to obtain consistent estimates from our DD and DDD specifications, we have had to assume that, without any intervention from the parents, children from different groups of maternal LOC share the same unobserved natural development trend on average. This is a strong assumption, and there is probably no way to formally test this hypothesis and thus reject such concerns definitively. Nevertheless, we still believe that our obtained estimates from the DD and DDD specifications are closer in terms of magnitudes to the true parameters than those obtained by FD. Moreover, it is important to note that our empirical strategy is more suitable for the estimation of the skill production function during the preschool period where parental inputs are the predominant type of investment.

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Tables 1A-1C: Probabilities of success and failure and net returns to investment by type of investment

Parental \ Nature	Success	Fail
Success	$p_p p_N$	$p_p(1-p_N)$
Fail	$(1-p_p)p_N$	$(1-p_p)(1-p_N)$

Table 1A: probabilities

Parental \ Nature	Success	Fail
Success	$f(I_p)$+ $f(I_N)-c$	$f(I_p)-c$
Fail	$f(I_N)-c$	$-c$

Table 1B: Net returns if parent invests

Parental \ Nature	Success	Fail
Success	$f(I_N)$	0
Fail	$f(I_N)$	0

Table 1C: Net returns if parent does not invest

Figure 1: Maternal Beliefs and Locus of Control

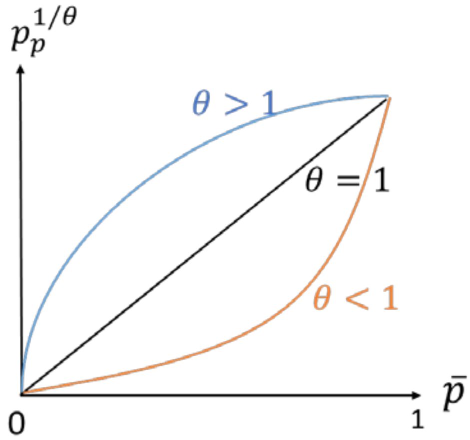

Table 2A: Maternal locus of control and child’s educational attainment and emotional wellbeing at aged 16

Panel A: Standardized total GCSE score (N=2,355)	**(1)**	**(2)**	**(3)**	**(4)**
Maternal LOC: Neutral	0.486***	0.127***	0.126***	0.112***
	[0.053]	[0.036]	[0.036]	[0.036]
Maternal LOC: Internal	0.778***	0.211***	0.208***	0.172***
	[0.055]	[0.038]	[0.038]	[0.038]
Child LOC: Neutral			0.034	0.032
			[0.025]	[0.025]
Child LOC: Internal			0.067**	0.05
			[0.034]	[0.034]
Mother completed A-level				0.127***
				[0.021]
Male child	-0.208***	-0.168***	-0.170***	-0.165***
	[0.031]	[0.023]	[0.023]	[0.022]
R-squared	***0.103***	***0.624***	***0.624***	***0.629***
Panel B: Standardized SMFQ-198 (N=1,566)	**(5)**	**(6)**	**(7)**	**(8)**
Maternal LOC: Neutral	0.202**	0.176**	0.169*	0.160*
	[0.097]	[0.087]	[0.088]	[0.089]
Maternal LOC: Internal	0.213**	0.167*	0.158*	0.142
	[0.098]	[0.090]	[0.091]	[0.093]
Child LOC: Neutral			0.023	0.022
			[0.056]	[0.056]
Child LOC: Internal			0.075	0.07
			[0.068]	[0.068]
Mother completed A-level				0.046
				[0.048]
Male child	0.407***	0.251***	0.249***	0.250***
	[0.045]	[0.045]	[0.045]	[0.045]
R-squared	***0.052***	***0.209***	***0.209***	***0.210***
Characteristics at birth	*N*	*Y*	*Y*	*Y*
Life events b/w ages 9 and 11	*N*	*Y*	*Y*	*Y*
Prior attainments	*N*	*Y*	*Y*	*Y*

Note: *<10%; **<5%; ***<1%. Panel A’s dependent variable is standardized GCSE average total score measured at age 16, while Panel B’s dependent variable is standardized mother-assessed SMFQ score measured at age 16. Robust standard errors are in parentheses. Each regression controls for gender, school age cohort at GCSE level. Characteristics at birth include birth weight, weeks of gestation, head circumference at birth, crown-heel length, number of siblings age 0 to 15 years old, number of siblings aged 16 to 18, mother’s age at birth. Prior attainments are Key Stage 2 at age 10 (Math, English, Science), IQ at age 9, MacArthur scores at age 3. Life events are dummies for each event occurred to the cohort member (or her family) during age 9 and 11 namely: parent death, sibling death, relatives death, family illness, parents’ relationship, mother's pregnancy, family income situation, family employment situation, financial difficulties, housing situations. Mother's LOC is measured at week 12 of gestation. The cohort member's LOC is measure at age 9. Neutral LOC consists of those with the measure falls within the middle quartiles. Internal LOC consists of those with the measure is at 1st quartile or under.

Table 2B: Maternal locus of control and early child outcomes at aged 1-3

	MacArthur Receptive Score (MRS)			**MacArthur Expressive Score (MES)**			**EAS Temperament Score (EASTS)**		
	Age 1	***Age 2***	***Age 3***	***Age 1***	***Age 2***	***Age 3***	***Age 1***	***Age 4***	***Age 5***
Maternal Neutral LOC	0.143***	0.131***	0.108**	0.103**	-0.016	0.101**	0.063	0.043	0.062
	[0.032]	[0.044]	[0.044]	[0.042]	[0.041]	[0.044]	[0.049]	[0.048]	[0.050]
Maternal Internal LOC	0.188***	0.149***	0.119**	0.083*	-0.088**	0.090*	0.080	0.091*	0.090*
	[0.034]	[0.049]	[0.048]	[0.046]	[0.045]	[0.048]	[0.053]	[0.052]	[0.054]
Mother completed A-level	0.017	0.154***	0.105***	0.110***	0.006	0.083***	0.086***	0.137***	0.113***
	[0.019]	[0.029]	[0.027]	[0.029]	[0.027]	[0.027]	[0.031]	[0.030]	[0.030]
Male child	-0.142***	-0.336***	-0.235***	-0.476***	-0.267***	-0.268***	-0.203***	-0.138***	-0.153***
	[0.018]	[0.028]	[0.024]	[0.028]	[0.026]	[0.025]	[0.029]	[0.029]	[0.029]
Observations	4,940	4,940	4,940	4,940	4,940	4,940	3,892	3,892	3,892
R-squared	0.059	0.064	0.045	0.075	0.046	0.050	0.030	0.044	0.052

Note: *<10%; **<5%; ***<1%. Dependent variables are standardized Receptive MacArthur score (at aged 1, 2 and 3), standardized Expressive MacArthur score (at aged 1, 2 and 3), and standardized EAS Temperament score (at aged 3, 4 and 5), respectively. Robust standard errors are in parentheses. Each regression controls for gender, characteristics at birth and prior life events (see Table 2A's note).

Table 3A: Mother's attitudes towards parenting (at 32 weeks in gestation)

	Babies need stimulation to develop	Babies should not be disturbed much	Parents should adapt life for baby	Baby should fit into parents routine	Babies developm ent should be natural	Important to talk to babies of all ages
Maternal Neutral LOC	0.129***	-0.03	0.187***	-0.146**	-0.197***	0.015**
	[0.028]	[0.058]	[0.058]	[0.058]	[0.058]	[0.007]
Maternal Internal LOC	0.180***	-0.077	0.345***	-0.200***	-0.286***	0.015*
	[0.029]	[0.063]	[0.063]	[0.063]	[0.063]	[0.008]
Mother completed A-level	0.043***	0.080**	0.195***	-0.124***	-0.005	0.001
	[0.014]	[0.037]	[0.038]	[0.037]	[0.038]	[0.005]
Male child	-0.012	-0.026	0.062*	-0.034	0.029	-0.001
	[0.015]	[0.037]	[0.037]	[0.036]	[0.037]	[0.004]
Observations	4,016	3,991	4,011	3,990	3,928	4,044
R-squared	0.045	0.006	0.041	0.02	0.027	0.014

Note: *<10%; **<5%; ***<1%. Dependent variables are scores on mother's attitudes towards parenting, questioned at gestation week 32. Robust standard errors are in parentheses. Each regression controls for gender, characteristics at birth, background of mother's childhood (see Table 2A's note).

Table 3B: Mother's attitudes towards parenting (at 8 months)

	Babies need stimulation to develop	Babies should not be disturbed much	Parents should adapt life to baby	Babies should fit into parents routine	Babies development should be natural
Maternal Neutral LOC	0.145***	0.017	0.285***	-0.125**	-0.174***
	[0.030]	[0.060]	[0.063]	[0.061]	[0.063]
Maternal Internal LOC	0.189***	0.042	0.449***	-0.140**	-0.216***
	[0.030]	[0.066]	[0.069]	[0.066]	[0.069]
Mother completed A-level	0.004	-0.005	0.281***	-0.111***	0.069*
	[0.012]	[0.038]	[0.041]	[0.039]	[0.041]
Male child	-0.017	-0.029	0.000	0.035	-0.008
	[0.013]	[0.037]	[0.040]	[0.038]	[0.040]
Observations	4,030	4,009	4,000	3,984	3,947
R-squared	0.034	0.008	0.056	0.016	0.016

Note: *<10%; **<5%; ***<1%. Dependent variables are scores on mother's attitudes towards parenting, questioned at 8 months. Robust standard errors are in parentheses. Each regression controls for gender, characteristics at birth, background of mother's childhood (see Table 2A's note).

Table 3C: Father’s attitudes towards parenting (at 8 months)

	Likes to play with child	Pleasure in child development	Active in child upbringing	Babies development should be natural
Maternal Neutral LOC	0.013	0.023	0.073**	-0.245
	[0.033]	[0.024]	[0.035]	[0.165]
Maternal Internal LOC	-0.012	0.025	0.068*	-0.22
	[0.036]	[0.025]	[0.037]	[0.174]
Paternal Neutral LOC	0.049*	0.049**	0.002	-0.048
	[0.029]	[0.021]	[0.030]	[0.142]
Paternal Internal LOC	0.025	0.038*	-0.012	0.078
	[0.033]	[0.023]	[0.034]	[0.157]
Mother completed A-level	0.013	-0.006	0.040**	0.028
	[0.020]	[0.011]	[0.018]	[0.089]
Father completed A-level	0.000	-0.003	0.003	0.002
	[0.020]	[0.012]	[0.019]	[0.089]
Male child	-0.062***	-0.022*	-0.033*	0.339***
	[0.018]	[0.011]	[0.017]	[0.084]
Observations	2,696	2,696	2,696	2,696
R-squared	0.055	0.049	0.044	0.053

Note: *<10%; **<5%; ***<1%. Dependent variables are scores on beliefs about parenting of father, questioned when the cohort child aged 8 months. Robust standard errors are in parentheses. Each regression controls for gender, characteristics at birth, and background of mother’s childhood (see Table 2A’s note).

Table 4A: Mother's investment in stimulating activities at different ages

	Age 1		Age 4		Age 5	
Maternal Neutral LOC	0.154***	0.144***	0.215***	0.205***	0.202***	0.192***
	[0.032]	[0.032]	[0.036]	[0.036]	[0.038]	[0.038]
Maternal Internal LOC	0.203***	0.177***	0.274***	0.249***	0.257***	0.231***
	[0.037]	[0.038]	[0.040]	[0.041]	[0.043]	[0.044]
Mother completed A-level		0.082***		0.077***		0.074***
		[0.024]		[0.027]		[0.028]
Male child	-0.045*	-0.042*	-0.112***	-0.109***	-0.116***	-0.113***
	[0.024]	[0.024]	[0.026]	[0.026]	[0.027]	[0.027]
Observations	7,092	7,092	6,254	6,254	5,696	5,696
R-squared	0.064	0.066	0.046	0.047	0.036	0.038

Note: *<10%; **<5%; ***<1%. Dependent variables are indices measuring score at age 0-1 of parents' activities with the cohort member outdoors (developmental stimulating outside activities and shopping activities), parents' developmental stimulating activities, parents' caring activities, parents' playing activities. Robust standard errors are in parentheses. Each regression controls for gender, characteristics at birth, and background of mother's childhood (see Table 2A's note).

Table 4B: Lagged-dependent parental time investment regressions with maternal LOC

VARIABLES	Active outside Aged 3.5	Active outside Aged 5	Passive outside Aged 3.5	Passive outside Aged 5	Maternal cognitive stimulation Aged 3.5	Maternal cognitive stimulation Aged 5	Paternal cognitive stimulation Aged 3.5	Paternal cognitive stimulation Aged 5
Maternal Neutral LOC	0.056*	-0.010	-0.027	-0.150***	0.101***	0.022	0.063*	0.089**
	[0.033]	[0.035]	[0.034]	[0.034]	[0.036]	[0.037]	[0.036]	[0.037]
Maternal Internal LOC	0.093**	-0.056	-0.080**	-0.238***	0.139***	0.029	0.123***	0.079**
	[0.038]	[0.038]	[0.038]	[0.038]	[0.039]	[0.039]	[0.039]	[0.040]
Mother completed A-level	0.050**	-0.069***	-0.103***	-0.067***	0.015	0.040*	0.005	-0.021
	[0.024]	[0.025]	[0.024]	[0.024]	[0.024]	[0.023]	[0.023]	[0.023]
Male child	0.033	0.006	-0.046**	-0.041*	-0.051**	-0.033	0.011	-0.084***
	[0.023]	[0.024]	[0.023]	[0.023]	[0.023]	[0.023]	[0.023]	[0.023]
Previous activity at aged 1.5	0.530***		0.462***		0.491***		0.562***	
	[0.012]		[0.014]		[0.014]		[0.012]	
Previous activity at aged 3.5		0.513***		0.513***		0.550***		0.590***
		[0.013]		[0.013]		[0.013]		[0.012]
Observations	6,046	5,673	6,024	5,637	6,045	5,672	5,595	5,195
R-squared	0.288	0.279	0.244	0.304	0.258	0.316	0.33	0.362

Note: *<10%; **<5%; ***<1%. Also see Table 2A's notes.

Table 5A: Using maternal LOC to estimate the returns to different parental investment on MacArthur: Receptive scores

	FD			DD			DDD		
	Age 1-2	**Age 2-3**	**Age 1-3**	**Age 1-2**	**Age 2-3**	**Age 1-3**	**Age 1-2**	**Age 2-3**	**Age 1-3**
Maternal cognitive stimulation	0.0353***	0.0198	0.0161	0.144***	0.159***	0.101***	0.147***	0.159***	0.104***
	[0.0121]	[0.013]	[0.0111]	[0.009]	[0.0112]	[0.0097]	[0.0094]	[0.0112]	[0.0097]
Maternal basic care		-0.0236**			-0.0151*			-0.0157**	
		[0.0114]			[0.0079]			[0.0079]	
Maternal play with the child	0.0073	-0.0226*	-0.0127	0.0138	-0.0269**	-0.0033	0.0118	-0.0268**	-0.0056
	[0.0123]	[0.0129]	[0.0129]	[0.0092]	[0.0108]	[0.0099]	[0.0092]	[0.0108]	[0.0099]
Paternal cognitive stimulation	0.0063	0.0402***	0.0112	0.0371***	0.0893***	0.0211**	0.0338***	0.0866***	0.0185*
	[0.0123]	[0.0126]	[0.0119]	[0.0102]	[0.0114]	[0.0100]	[0.0102]	[0.0114]	[0.0101]
Paternal basic care	0.0196*	-0.0087	-0.0078	0.00217	-0.0128	0.00093	0.00115	-0.0166*	0.00043
	[0.011]	[0.0118]	[0.0108]	[0.0085]	[0.0093]	[0.0087]	[0.0085]	[0.0093]	[0.0088]
Paternal play with the child	0.0011	-0.0076	-0.0147	0.0367***	-0.0156	0.0109	0.0420***	-0.0116	0.0156
	[0.0123]	[0.0137]	[0.0126]	[0.0101]	[0.0114]	[0.0102]	[0.0101]	[0.0114]	[0.0103]
Passive outside	-0.0081	0.00358	0.004	-0.0241***	-0.0057	-0.0180**	-0.0251***	-0.0018	-0.0196**
	[0.011]	[0.0118]	[0.0114]	[0.0078]	[0.0084]	[0.0081]	[0.0078]	[0.0085]	[0.0083]
Active outside	0.0176	0.0315***	0.0317***	0.0563***	0.0769***	0.0428***	0.0554***	0.0727***	0.0432***
	[0.012]	[0.0119]	[0.0111]	[0.008]	[0.0091]	[0.0085]	[0.0082]	[0.0091]	[0.0085]
FD observations	7,741	6,817	6,901						
DD and DDD observations				15,441	14,065	14,642	15,441	14,065	14,642
R-squared	0.003	0.005	0.004	0.076	0.077	0.047	0.075	0.079	0.045

Note: *<10%; **<5%; ***<1%. For FD, the regressions are controlled for maternal alcohol behaviour (unit drinks), maternal cigarette intake, maternal physical health (self-assessed), hours of child care by family members in a week, childcare by commercial premises in a week, maternal mental health (CCEI: anxiety and depression subscales). For DD, control variables are of FD with year dummies and LOC dummies. For DDD, control variables are of DD with Year*LOC dummies, Year*EDU dummies, EDU*LOC dummies (the double-interaction terms from the three sources of variation).

Table 5B: Using maternal LOC to estimate the returns to different parental investment on MacArthur: Expressive scores

	FD			DD			DDD		
	Age 1-2	**Age 2-3**	**Age 1-3**	**Age 1-2**	**Age 2-3**	**Age 1-3**	**Age 1-2**	**Age 2-3**	**Age 1-3**
Maternal cognitive stimulation	0.0472***	0.0211	0.0340***	0.165***	0.146***	0.134***	0.165***	0.146***	0.132***
	[0.0118]	[0.0131]	[0.0123]	[0.0091]	[0.0106]	[0.0097]	[0.009]	[0.0105]	[0.0097]
Maternal basic care		-0.0088			-0.0049			-0.0057	
		[0.0122]			[0.0083]			[0.0084]	
Maternal play with the child	0.00914	-0.0144	-0.0332***	0.0035	-0.0318***	-0.0189**	0.0031	-0.0317***	-0.0183**
	[0.0112]	[0.0132]	[0.0127]	[0.008]	[0.0103]	[0.0086]	[0.008]	[0.0103]	[0.0086]
Paternal cognitive stimulation	0.0224*	0.0353***	0.0169	0.0926***	0.102***	0.0745***	0.0905***	0.0995***	0.0729***
	[0.0130]	[0.0136]	[0.0137]	[0.0108]	[0.0119]	[0.0110]	[0.0109]	[0.0119]	[0.011]
Paternal basic care	0.0297***	-0.0071	0.0131	-0.0011	-0.0043	-0.00761	-0.0036	-0.0075	-0.0108
	[0.0115]	[0.0127]	[0.0121]	[0.0086]	[0.0097]	[0.009]	[0.0086]	[0.0097]	[0.009]
Paternal play with the child	-0.0055	-0.0028	-0.023	0.0154	-0.0074	-0.0069	0.0170*	-0.0038	-0.0043
	[0.0123]	[0.0139]	[0.0141]	[0.0099]	[0.0115]	[0.0102]	[0.0099]	[0.0116]	[0.0102]
Passive outside	-0.0201*	-0.0003	-0.008	0.00839	0.003	0.0154*	0.0122	0.00684	0.0193**
	[0.0116]	[0.0116]	[0.0123]	[0.0082]	[0.0086]	[0.0086]	[0.0082]	[0.0087]	[0.0086]
Active outside	-0.00125	0.0129	0.0198*	0.0315***	0.0581***	0.0347***	0.0272***	0.0541***	0.0319***
	[0.0120]	[0.0123]	[0.0118]	[0.0083]	[0.0093]	[0.0088]	[0.0084]	[0.0094]	[0.0088]
Observations	7,741	6,817	6,901	15,441	14,065	14,642	15,441	14,065	14,642
R-squared	0.006	0.002	0.006	0.088	0.081	0.054	0.089	0.082	0.056

Note: *<10%; **<5%; ***<1%. See also Table 5A's notes.

Appendix A: Rotated Factor Loadings EAS Temperament Questionnaire

	38 Months		57 Months		69 Months	
	Factor 1	**Factor 2**	**Factor 1**	**Factor 2**	**Factor 1**	**Factor 2**
Frequency of child cries easily	-0.0785	0.7470	-0.0085	0.7570	-0.0284	0.7264
Frequency of child is somewhat emotional	0.0564	0.7213	0.0404	0.7159	0.0594	0.7304
Frequency of child fusses and cries	0.0135	0.7785	-0.0124	0.7508	-0.0140	0.7439
Frequency of child gets upset easily	-0.0481	0.8134	-0.0462	0.8156	-0.0388	0.8151
Frequency of child reacts intensely when upset	0.1034	0.5586	0.0409	0.5922	0.0306	0.5791
Frequency of child is always on the go	0.5865	0.1079	0.5930	0.0827	0.6081	0.0976
Frequency of child is off and running as soon as wakes up	0.5151	0.0880	0.5431	0.0563	0.5574	0.0808
Frequency of child is very energetic	0.6421	0.0893	0.6489	0.0187	0.6769	0.0469
Frequency of child prefers quiet inactive games to active games	-0.4161	0.0835	-0.4675	0.0364	-0.4613	0.0373
Frequency of child likes to be with people	0.6193	0.0279	0.5957	0.0716	0.5871	0.0218
Frequency of child prefers playing with others rather than alone	0.4793	0.1577	0.4344	0.1734	0.4205	0.1198
Frequency of child finds people more stimulating than anything else	0.5705	0.1546	0.5449	0.1483	0.5458	0.1428
Frequency of child is something of a loner	-0.5022	0.1293	-0.5358	0.1171	-0.5324	0.1457
Frequency of child tends to be shy	-0.5534	0.1642	-0.5153	0.1095	-0.4921	0.0952
Frequency of child makes friends easily	0.6650	-0.0870	0.6105	-0.0892	0.5756	-0.1320
Frequency of child is very sociable	0.7749	-0.0608	0.7247	-0.0736	0.7136	-0.0854
Frequency of child takes a long time to warm to strangers	-0.4907	0.1765	-0.5204	0.0871	-0.4917	0.0752
Frequency of child is very friendly with strangers	0.5376	-0.0006	0.4735	0.0380	0.4581	0.0600

Appendix B: Adult Nowicki and Strickland Internal-External scale of Locus of Control at 12 weeks gestation.

1. Did getting good marks at school mean a great deal to you?
2. Are you often blamed for things that just aren't your fault?
3. Do you feel that most of the time it doesn't pay to try hard because things never turn out right anyway?
4. Do you feel that if things start out well in the morning that it's going to be a good day no matter what you do?
5. Do you believe that whether or not people like you depends on how you act?
6. Do you believe that when good things are going to happen they are just going to happen no matter what you try to do to stop them?
7. Do you believe that when bad things are going to happen they are just going to happen no matter what you try to do to stop them?
8. Do you feel that when someone doesn't like you there's little you can do about it?
9. Did you usually feel that it was almost useless to try in school because most other children were cleverer than you?
10. Are you the kind of person who believes that planning ahead makes things turn out better?
11. Most of the time, do you feel that you have little to say about what your family decides to do?
12. Do you think it's better to be clever than to be lucky?

Appendix C: Nowicki and Strickland scale of Locus of Control for preschool and primary children reported at ALSPAC clinic when study child is 9 years

1. Do you feel that wishing can make good things happen?
2. Are people nice to you no matter what you do?
3. Do you usually do badly in your school work even when you try hard?
4. When a friend is angry with you is it hard to make that friend like you again?
5. Are you surprised when your teacher praises you for your work?
6. When bad things happen to you is it usually someone else's fault?
7. Is doing well in your class-work just a matter of 'luck' for you?
8. Are you often blamed for things that just aren't your fault?
9. When you get into an argument or fight is it usually the other person's fault?
10. Do you think that preparing for tests is a waste of time?
11. When nice things happen to you is it usually because of 'luck'?
12. Does planning ahead make good things happen?

Appendix D: Summary of parental activities, by index group

Variable component	Month 6	Month 18	Month 30	Month 42	Month 57	Month 69	Month 81
Outside passive							
Take to local shops	x	x	x	x	x	x	x
Take to department store	x	x	x	x	x	x	x
Take to supermarket	x	x	x	x	x	x	x
Outside active							
Take to park or playground					x	x	x
Take to park	x	x	x	x	x	x	x
Take to friends/family	x	x	x	x	x	x	x
Take for a walk	x	x		x			
Take to library		x	x	x	x	x	x
Take to places of interest		x	x	x	x	x	x
Maternal cognitive stimulation							
Talks to CH while working	x			x	x		x
Sing to CH	x	x		x	x	x	x
Teach CJ	x	x		x			
Read to CH	x	x		x	x	x	x
Draw or paint with CH					x	x	x
Maternal playing							
Play with toys	x	x		x	x	x	x
Any play	x	x		x			
Physical/active play	x	x		x	x	x	x
Make things with CH					x	x	x
Maternal basic care							
Bath		x		x	x	x	x
Feed or prepare food		x		x	x	x	x
Put to bed					x	x	x
Paternal cognitive stimulation							
Sing to CH	x	x		x	x	x	x
Read to CH	x	x		x	x	x	x
Take for a walk	x	x		x			
Take to playground					x	x	x
Draw or paint with CH					x	x	x
Have conversations with CH							x
Does homework with CH							x
Helps CH prepare for school							x
Paternal playing							
Play using toys	x	x		x	x	x	x
Physical/active play	x	x		x	x	x	x
Any play	x	x		x			

Makes things with CH					x	x	x
Paternal basic care							
Bath	x	x		x	x	x	x
Feed or prepare food	x	x		x	x	x	x
Put CH to bed					x	x	x

Appendix E: Summary statistics of early childhood characteristics by maternal locus of control and education

	Maternal education: High school graduates				**Maternal education: Lower than high school**			
	Maternal locus of control				**Maternal locus of control**			
	Bottom quartile (extremely internal)	**Q2**	**Q3**	**Top quartile (extremely external)**	**Bottom quartile (extremely internal)**	**Q2**	**Q3**	**Top quartile (extremely external)**
Mom's locus of control at pregnancy	1.40	3.00	4.46	7.09	1.53	3.00	4.50	7.04
Dad's locus of control at pregnancy	2.09	2.47	3.00	4.20	2.90	3.33	3.72	4.43
Male	0.51	0.52	0.52	0.50	0.54	0.51	0.52	0.52
Birth weight (grams)	3451.15	3426.87	3392.33	3266.42	3441.84	3411.59	3394.00	3365.92
Weeks of gestation	39.37	39.38	39.16	39.04	39.48	39.54	39.47	39.46
Head circumference	34.94	34.84	34.84	34.51	34.80	34.74	34.73	34.68
Crown-heel length	50.84	50.70	50.71	50.20	50.81	50.75	50.58	50.41
Aged 0-15 lived with child, week 8	0.71	0.70	0.81	1.05	0.78	0.85	0.85	1.01
Aged 16-18 lived with child, week 8	0.02	0.01	0.02	0.08	0.02	0.04	0.04	0.07
Mother age at childbirth	30.90	30.05	29.52	27.34	28.25	28.07	27.74	26.70
Partner lived with mom at birth	0.98	0.97	0.95	0.89	0.97	0.96	0.95	0.89
Dad lived with at birth	0.98	0.97	0.95	0.89	0.96	0.95	0.95	0.89

Appendix F: Cohort aged 0-1

	Passive outside	Active outside	Maternal cognitive stimulation	Maternal play	Maternal basic care	Paternal cognitive stimulation	Paternal cognitive stimulation	Paternal basic care
Maternal Neutral LOC	-0.048	0.124***	0.144***	0.075**	0.034	0.057	0.098**	0.153***
	[0.033]	[0.033]	[0.032]	[0.033]	[0.034]	[0.046]	[0.046]	[0.043]
Maternal Internal LOC	-0.126***	0.151***	0.177***	0.074*	0.008	0.085	0.112**	0.196***
	[0.038]	[0.038]	[0.038]	[0.038]	[0.039]	[0.052]	[0.051]	[0.048]
Paternal Neutral LOC						0.059	-0.017	0.025
						[0.045]	[0.044]	[0.042]
Paternal Internal LOC						0.018	-0.076	0.006
						[0.053]	[0.052]	[0.049]
Mother completed A-level	0.032	0.186***	0.082***	0.032	0.036	0.122***	0.122***	0.063**
	[0.025]	[0.025]	[0.024]	[0.025]	[0.025]	[0.034]	[0.033]	[0.031]
Father completed A-level						0.055	0.05	-0.022
						[0.033]	[0.033]	[0.031]
Male child	-0.052**	-0.019	-0.042*	-0.018	-0.017	0.044	-0.056*	0.029
	[0.024]	[0.024]	[0.024]	[0.024]	[0.025]	[0.031]	[0.030]	[0.029]
Observations	7,091	7,097	7,092	7,090	6,820	4,417	4,419	4,432
R-squared	0.037	0.021	0.066	0.024	0.008	0.044	0.063	0.062

Appendix G: Cohort aged 4-5

	Shopping	Stimulating outside	Mother's stimulating the child	Mother's playing with the child	Mother's caring the child	Father's stimulating the child	Father's playing with the child	Father's caring the child
Maternal Neutral LOC	-0.143***	0.007	0.192***	0.081**	0.165***	0.242***	0.185***	0.109**
	[0.039]	[0.036]	[0.038]	[0.039]	[0.039]	[0.054]	[0.054]	[0.047]
Maternal Internal LOC	-0.327***	-0.040	0.231***	0.084*	0.174***	0.274***	0.257***	0.157***
	[0.044]	[0.042]	[0.044]	[0.044]	[0.044]	[0.059]	[0.059]	[0.052]
Paternal Neutral LOC						0.196***	0.099*	0.154***
						[0.052]	[0.052]	[0.045]
Paternal Internal LOC						0.201***	0.061	0.135***
						[0.060]	[0.060]	[0.052]
Mother completed A-level	-0.148***	-0.027	0.074***	-0.012	-0.016	0.023	-0.037	0.132***
	[0.028]	[0.027]	[0.028]	[0.028]	[0.028]	[0.037]	[0.037]	[0.032]
Father completed A-level						0.063*	0.029	0.010
						[0.037]	[0.037]	[0.033]
Male child	-0.086***	-0.01	-0.113***	-0.053*	-0.077***	-0.112***	0.226***	0.021
	[0.027]	[0.026]	[0.027]	[0.027]	[0.028]	[0.034]	[0.034]	[0.030]
Observations	5,516	5,987	5,696	5,695	5,696	3,513	3,513	3,694
R-squared	0.06	0.028	0.038	0.022	0.007	0.047	0.056	0.029

Note: *<10%; **<5%; ***<1%.