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Working paper

25/52

Intimate partner violence and children's human capital

Economic and Social Research Council

Intimate Partner Violence and Children's Human Capital*

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November 3, 2025

Abstract

We use a dynamic latent factor model to study how exposure to intimate partner violence (IPV) affects young children's accumulation of cognitive and socio-emotional skills. The model allows for both a *direct* effect of exposure as well as *indirect* effects via changes in parental investments and mother's mental health. IPV has adverse effects on both skills, with more immediate and larger effects for socio-emotional skills and with the skill deficits growing in exposure duration. The indirect effects dominate for both skills. Early interventions that support parental investment and mother's mental health have potential for offsetting the adverse IPV-effects but only if subsequent IPV exposure is eliminated.

Keywords: Intimate partner violence, skill development, mental health, ALSPAC.

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*We thank Monica Costa Dias and Emily Nix for valuable insights and seminar audiences at Mannheim (Families in Macroeconomics), Barcelona (WomEmpower), the LSE (Early Interventions and Human Capital) and the University of Surrey for helpful comments. We are finally extremely grateful to all the families who took part in the ALSPAC study, the midwives for their help in recruiting them, and the entire ALSPAC team. The UK Medical Research Council and Wellcome (Grant ref: 217065/Z/19/Z) and the University of Bristol provide core support for ALSPAC. Funding for the current project was provided by the ESRC (ES/V016067/1). Alexander Vickery gratefully acknowledges financial support from the British Academy (PF21/210126)

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1 Introduction

Intimate partner violence (IPV) remains one of the most pervasive forms of violence worldwide and is widely recognised as a pressing public health and social problem (Oram et al., 2022). The burden of IPV falls disproportionately on women: global estimates suggest that nearly one in three women have experienced physical or sexual violence by an intimate partner in their lifetime, with prevalence rates ranging from around 30 percent in high-income countries such as the UK and US to levels as high as 70–80 percent in parts of South Asia and Sub-Saharan Africa (OECD, 2022; World Health Organization, 2021). Beyond its physical and psychological harm, IPV is increasingly understood as a driver of persistent gender inequalities, constraining women's economic opportunities and shaping intergenerational cycles of disadvantage (Bergvall, 2024; Graf and Schechter, 2024).

Children growing up in households affected by IPV are also now recognised as victims in their own right. Exposure to toxic and violence environments during early childhood represents a major source of stress, with potential consequences for the development of cognitive and socio-emotional skills that underpin later life outcomes (Currie and Tekin, 2012; Wathen and MacMillan, 2013; Schurer et al., 2019; Moroni et al., 2025). Witnessing abuse can constitute both direct harm—through trauma and fear—and indirect harm, by reducing parental investments and undermining mother's mental health (Vu et al., 2016). Yet despite growing concern, rigorous evidence on the developmental consequences of IPV exposure for children remains limited, with most existing studies relying on small or selective samples and do not provide a full picture of the dynamics in the relationships. This leaves a critical gap in understanding how IPV shapes the early formation of human capital and through which mechanisms its effects unfold.

This paper contributes to the growing literature on the economics of early childhood by examining how exposure to IPV shapes the accumulation of cognitive and socio-emotional skills during the preschool years. Building on recent advances in the estimation of human capital production frameworks (Cunha and Heckman, 2007, 2008; Cunha et al., 2010; Attanasio et al., 2020, 2022; Agostinelli and Wiswall, 2016, 2025; Aucejo and James, 2021; Del Bono et al., 2022; Freyberger, 2025) we adopt a dynamic latent factor approach. We exploit the uniquely rich Avon Longitudinal Study of Parents and Children (ALSPAC), which provides repeated measures of IPV, parental investments, maternal mental health, and child skills. A particularly striking feature of our setting is the frequency of measurements of children's skills over the pre-school period. We are able to use that the ALSPAC children's skills were measured at four points in time between the ages of 6 and 52 months, enabling us to break the pre-school years down into three short development periods of just over a year each. This uniquely detailed timing is central to the research design – in particular the scope for tracing the impacts of IPV as a traumatic event that occurs in some years but not necessarily all years. In our analysis we allow for both direct effects of IPV exposure on children's skill development and indirect effects operating through changes in parental investments and maternal mental health as inputs and by capturing complementarities between skills and inputs over time, our model quantifies how early exposure to IPV reverberates across the children's early development.

A distinctive challenge in studying IPV is that it remains largely hidden. Only a minority of incidents ever reach official records, with police or hospital data reflecting only the most severe cases. As a result, reliance on administrative sources risks underestimating the prevalence of abuse and, with that, the full distribution of developmental consequences of IPV. Our analysis instead exploits a repeated mother self-reported measures, which provides a more comprehensive picture of children's early years exposure. This feature of the data allows us to move beyond the "tip of the iceberg" of reported cases and capture the significantly more pervasive, but less visible, forms of toxicity that are likely to shape child development.

For our estimation, we adopt the two-step approach developed by Aucejo and James (2021) that separates estimation of the descriptive measurement system from the structural skill production function. This has two advantages in our setting. First, initially recovering the distribution of latent cognitive and socio-emotional skills allows us to describe the dynamic association between IPV exposure and skill development using Bartlett factor scores and subsequently use this description to also assess the fit of our model. Second, the two-step approach offers a flexible and tractable way to estimate the production technologies while accommodating binary and discrete mother and child characteristics and, critically, IPV incidence. In this way, the two-step approach underpins both the descriptive and analytical components of our analysis.

Our analysis is organised around three core questions. First, what are the *total* effects of children's exposure to IPV on the development of cognitive and socio-emotional skills during the preschool years? Second, to what extent do these effects operate *directly* through the experience of IPV itself, as opposed to *indirectly* through reduced parental investments and diminished maternal mental health? Third, what do these mechanisms imply for the scope of *early intervention* policies aimed at supporting mothers and young children to mitigate the negative consequences of IPV exposure?

We begin by estimating the total effects of IPV exposure on children's early skill development, initially descriptively and then structurally. We find clear evidence of adverse impacts on both socio-emotional and cognitive skills. The effects are larger and more immediate for socio-emotional skills, for which exposure to IPV in the first years of life leads to noticeable and persistent deficits. For cognitive skills, the negative impacts are smaller in magnitude and emerge more gradually, but nevertheless remain significant over time. In quantitative terms, children exposed to IPV fall behind by roughly 2–7 percentiles in the skill distributions by the end of the pre-school years.

Decomposing the total effects reveals that most of the adverse impact of IPV on children operates indirectly rather than directly: the larger portion of skill deficits – specifically in the key years up to the age of three – arises indirectly through reductions in parental investments and adverse effects on maternal mental health. The highlighted importance of these indirect mechanisms in turn provides a direct link to early intervention policy aimed at supporting mothers and children particularly from adverse home environments.

Early-intervention programmes such as Sure Start in the UK are often multi-component, seeking to enhance both parent-child interactions and maternal well-being. Indeed, our simulated policy-analysis highlights how the multi-component design is essential for early interventions' ability to mitigate the IPV-generated deficits, and how the components reinforce each other due to complementarities in the skill production function. Nevertheless, a central message from our analysis is that – for early interventions to have meaningful mitigating effects – it is imperative that future IPV is also prevented.

Studies in economics on the impact of IPV on child outcomes have either focused IPV occurring during pregnancy (Aizer, 2011; Currie et al., 2022) or on child mortality (Rawlings and Siddique, 2020).[1] The paper most closely linked to ours is Bhuller et al. (2023), which uses Norwegian data to estimate the effects of police-reported IPV on outcomes for mothers and children (who are of various ages), including mental health diagnosis, child-protection, national test-scores.[2] A key challenge with using administrative data to study the effects of IPV is that the abuse will in the vast majority of cases have started well before any official reporting occurs. This was recently highlighted by Chang et al. (2025) using data from Taiwan that includes not only information on when a reported IPV incident occurred, but also information provided by the victim on how long the violence had lasted before that. They find that the average time between onset of IPV and help-seeking through an official channel (police, hospital etc.) is on average 2.5 years. Moreover, they find that victim's employment rates decrease after the onset of violence, but show signs of recovery following reporting, indicating that official reporting appears to serve – at least for some victims – as a "turning point". Based on a similar logic and using data from Finland, Adams et al. (2024) focus their study on the outcomes from the very start of cohabitation of women who subsequently will file an IPV report to the police. For this reason we will explore carefully if our mother-reported IPV measure indeed appears to correctly pinpoint the onset of IPV by checking that abuse does not have any impact of children's skills prior to its indicated onset.

The remainder of the paper is organized as follows. We first describe the ALSPAC data in Section 2. Our model of skill development and our estimation procedure is introduced in Section 3. We present our main results in Section 4. We present decompositions and policy simulations in Sections 5 and 6. Finally, Section 7 concludes.

[1] The economic literature has over the past 15 years contribute mainly to our understanding of the determinants of IPV. Determinants that have been considered in the literature include economic factors such as relative earnings, unemployment, cash transfers and health factors (Aizer, 2010; Heath et al., 2020; Hidrobo et al., 2016; Bhalotra et al., 2025; Papageorge et al., 2021) as well as cultural and institutional factors such as family structure and law enforcement (Tur-Prats, 2019; Chalfin et al., 2023; Miller and Segal, 2019; Amaral et al., 2021). The research on the consequences of IPV for women's employment and divorce and employment is more limited (Anderberg et al., 2023; Adams et al., 2024; Chang et al., 2025).

[2] Another example of a toxic or adverse home environment that children may be exposed to — and that has been extensively studied in the economics literature — is parental divorce. Evidence shows that early-childhood divorce is associated with lower cognitive and socio-emotional skills, reduced adult earnings, and higher risks of teen births and mortality (Johnston et al., 2025; Moroni and Vickery, 2025). However, these effects likely reflect not only the effect of divorce itself but also concurrent stressors—such as parental conflict, mental health crises or domestic violence—that both precipitate divorce and directly harm children.

2 Data: ALSPAC

The data used for the current study comes from the Avon Longitudinal Study of Parents and Children (ALSPAC) which started in the early 1990s.[3] Whilst the ALSPAC study is still ongoing, our focus will be on the time up to when the study child was about five years of age. Over this period, rich data was collected using a combination of questionnaires and clinic visits. The ALSPAC is a uniquely suited dataset for the current purpose as it includes repeated information on the mother's self-experienced IPV and about her mental health. It further includes repeated measures of parental inputs, and, importantly, high-quality repeated measures of the study child's skills. The focus on the period up to the age of five means that we focus on the pre-school phase where child cognitive and non-cognitive skill development mainly occurs within the household context.

2.1 Sample Selection and Baseline Characteristics

Pregnant women resident in Avon, UK with expected dates of delivery between 1st April 1991 and 31st December 1992 were invited to take part in the ALSPAC study. 20,248 pregnancies have been identified as being eligible and the initial number of pregnancies enrolled was 14,541.[4] We exclude all cases where the same mother is associated with multiple children, including twins and triplets to have a one-to-one pairing of mothers to children.[5] To retain a balanced sample across our observation window, we exclude all children with missing information on: (ii) their mother's age and/or qualifications (1,630 sample children), (iii) the first post-birth mother-based questionnaire (1,412 sample children), (iv) IPV, birth, and/or partnership status (1,371 sample children) and any children with missing observations for: (v) measures of cognitive or socio-emotional skills (6,228 sample children), measures of parental investments (424 sample children) and measures

[3]Ethical approval for the study was obtained from the ALSPAC Ethics and Law Committee and the Local Research Ethics Committees.

[4]Please note that the study website contains details of all the data that is available through a fully searchable data dictionary and variable search tool. See http://www.bristol.ac.uk/alspac/researchers/our-data/. When the children were 7 years of age, an attempt was made to bolster the initial sample with eligible cases who had failed to join the study originally. As our focus is on birth to 5 years of age, these later added children are not used in our analysis.

[5]Due to the 21 month length of the sampling window, of the original 14,541 initial pregnancies, 338 were from a woman who had already enrolled with a previous pregnancy.

of mother's mental health (270 sample children). Our final estimation sample includes 3,074 sample children.

Data was collected from the study mothers both about themselves and the household using so-called "mother-based" questionnaires and also specifically about the study child using so-called "child-based" questionnaires.[6] Table 1 reports the mean and standard deviation for the baseline demographic characteristics of the child at birth and of the mother (when 32 weeks pregnant).

Table 1: Descriptive Statistics of the ALSPAC Sample

	Mean	Std. Dev.
a) Child at birth		
Birth weight (kg)	3.46	0.51
Gestation period (weeks)	39.58	1.61
Gender (female)	0.50	0.50
Birth parity	0.73	0.86
b) Mother at baseline		
Mother's age	28.73	4.21
Low academic qual.	0.17	0.37
Medium academic qual.	0.38	0.49
High academic qual.	0.45	0.50
Partner present	0.97	0.16
No. Obs.	3,074	

Notes: The estimation sample includes 3,074 ALSPAC mothers and their study children. The upper panel reports information on the birth conditions of the ALSPAC study child: birth weight, gestation period, gender and parity. The lower panel reports mother characteristics at baseline (32 weeks pregnant): her age, qualification and whether she lived with a partner at baseline. "Low" academic qualifications corresponds to either no academic qualification, a CSE, or a low grade GCSE (grades D to G). "Medium" academic qualifications corresponds to an O-level or a high grade GCSE (grades A-C). "High" academic qualification corresponds to an A-level, undergraduate, or postgraduate degrees.

2.2 IPV Incidence

Over the sample period used in the current analysis, the mother-based questionnaires included (approximately) annual questions on the experience of IPV. Specifically, the

[6] Data was also collected from the partners using so-called "partner-based" questionnaires and through clinic visits.

mothers were repeatedly asked if any of the following events indicating physical abuse and/or toxicity directed at them had occurred: "Your partner was physically cruel to you" and/or "Your partner was emotionally cruel to you". We combine the two questions into a single IPV indicator that takes the value of unity if either question was answered positively and zero otherwise.[7]

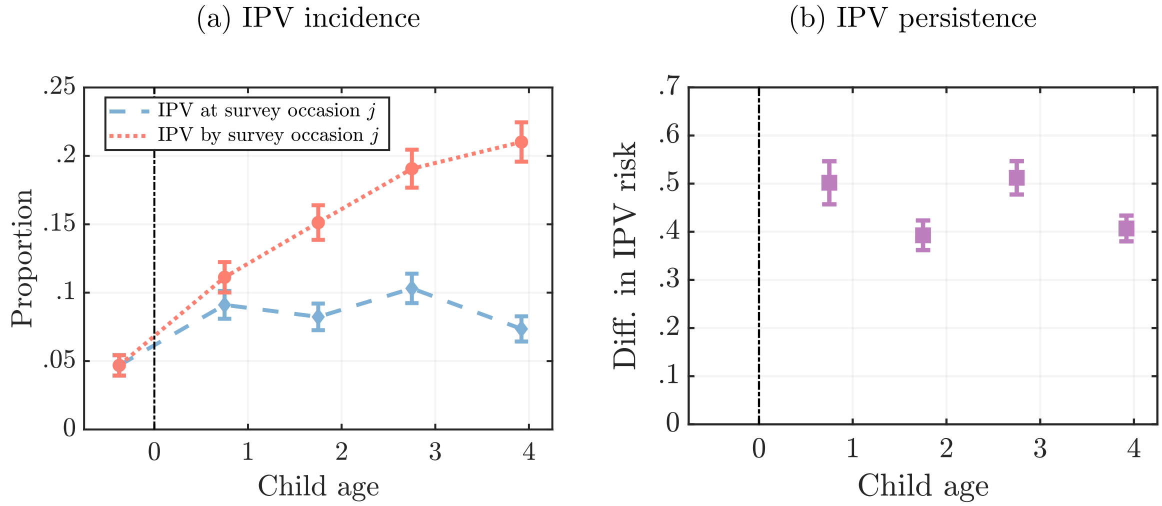
In total, the 3,074 ALSPAC mothers were asked about their experiences of IPV on five "occasions" before the end of our sample period: first when 32 weeks pregnant, and then when the child was 8, 21, 33, and 47 months old respectively. As our focus will be on children's early life exposure to IPV, in our skills development analysis below we will not make use of the IPV during pregnancy. Exposure to IPV in utero may affect birth outcomes as shown by Aizer (2011) and Currie et al. (2022) who found that IPV – as indicated by a police report for assault – during pregnancy led to reduced birth weights, a higher risk of pre-term birth and lower Apgar scores. In our skills development analysis below we include birth weight and gestational period length as child baseline characteristics in the first instance as determinants of children's initial skills, but also of subsequent skill growths and inputs. Moreover, in our subsequent analysis we will merge the first two post-birth IPV measurements to capture exposure during the child's earliest development period (see below). Nevertheless, for a complete description, we start here by showing the IPV dynamics across the full five measurement occasions.

Let $j = 1, \ldots, 5$ denote survey occasion. Figure 1 then illustrates the dynamics of IPV in the data. In Panel (a) we show the frequency of disclosed IPV *at* and *by* survey occasion. Panel (b) shows the persistence of IPV between survey occasions. Panel (a) shows that, post-birth, the IPV incidence is fairly stable between seven to ten percent. It further shows that, overall, 21.1 percent of the mothers in the sample disclose IPV on at least one occasion. This indicates that many of the mothers who indicate some IPV incidence do so on multiple occasions – that is, incidence is persistent. To highlight this persistence, Panel (b) plots the estimated coefficient from regressing the abuse indicator

[7]Each indicator for IPV incidence refers to the mother's self-reported experience of IPV within a reference period which is "since last asked", or, in the case of the first survey occasion "since becoming pregnant". Even though these measures are self-reported and open to subjective interpretation, the measured incidence of IPV in our sample is close – both in terms of levels and demographic correlates – to the best available measures of IPV in the UK in the late 1990s and early 2000s – based on the British Crime Survey – and also consistent with the lifetime incidence rate of IPV (26 percent) reported in that data (Walby and Allen, 2004).

at survey occasion j on the corresponding indicator at occasion $j-1$. This shows that a mother who disclosed abuse at the previous occasion is, on average, about 45 percentage points more likely to do so at the current occasion compared to a mother who did not do so, indicating strong IPV persistence.

Figure 1: Incidence of IPV



Notes: The ALSPAC mothers were asked about IPV incidence on five survey occasions, $j = 1, \ldots, 5$, before the end of our sample period: when 32 weeks pregnant and when the study child was 8, 21, 33, and 47 months old respectively. Panel (a) shows the incidence of any IPV (physical or emotional) *at* and *by* survey occasion j (where the vertical dashed line indicates the birth of the study child). Panel (b) illustrates the coefficients from regressing the binary IPV indicator at occasion j on the corresponding indicator at occasion $j-1$, that is estimating $q_{ij} = \alpha_j + \phi_j q_{i,j-1} + \epsilon_{ij}$. It thus shows the difference abuse frequency at j between mothers who indicated abuse at $j-1$ and mothers who did not. 95% confidence intervals are shown by error bars.

In Appendix A we further report how the IPV incidence of any abuse – either physical or emotional and at any of the five survey occasions – varies by birth and baseline characteristics. Figure A.1 highlights that the IPV incidence shows no particular relation to birth weight and gestation period. IPV incidence is highest for the youngest mothers and for mothers with low qualifications. IPV incidence is positively related to birth parity but unrelated to child gender.

Figure A.2 in Appendix A presents a data timeline. The lower part of the figure indicates that timing of the five IPV survey occasions, with the orange blocks indicating which period each refers to. In the skills development analysis below we will focus on three development periods. The first development period will be from the initial measurement of skills at six months of age to age two. The second development period then goes from two years of age to just over three, and the final development period then goes the measurement our final skill measurement at four years and four months. To capture IPV exposure in the first development period we will combine any IPV reported at the second and third survey occasion into a single indicator $q_{i,1}$ and we will use any IPV reported at the fourth and fifth survey occasions as indicators for the later two development periods, $q_{i,2}$ and $q_{i,3}$. We will make no further use of the in-pregnancy IPV measurement as our focus is on the child's post-birth exposure.

Whilst our data contains information about whether the mother lived with her partner in each period, we do not include partnership status in our skill development model. There are two reasons for this. First, separations are generally rare in our sample, even after IPV: over 90 percent of the mothers are observed to still live with their partner in next period following abuse.[8] Second, and more importantly, separations do not eliminate the risk of abuse but are often associated with an elevated risk of violence and harassment (Walby and Allen, 2004). Indeed, separations in our data do not lead to any discernible reductions in the risk of continued next-period abuse. Hence we focus on the mother's experiences of acts of abuse, not on the physical presence of her partner.

2.3 Skills and Inputs

A key challenge in the study of child human capital formation and development is that skills and inputs are never perfectly observed by the researcher and as such are latent. These latent skills and inputs are reflected in a set of observable, but noisy, measures. During the early years that we focus on, the ALSPAC data contains rich measures – from the child-based questionnaires – at four distinct (measurement) times $t = 1, \ldots, 4$, when the child was aged 6, 24, 38 and 52 months respectively. We define child i's *human capital* at time t as a vector $(\Theta^c_{it}, \Theta^e_{it})$ of two skills. The two skills considered are cognitive (c) and socio-emotional skills (e). We refer to skills at $t = 1$ as the child's "initial skills" and skills at $t = 4$ as their "terminal skills". Linking together the skill-measurement times are three *development periods*, $t = 1, 2, 3$, with inputs taking place in each period. The ALSPAC data contains a rich set of measures of two key inputs – parental investments and mother's mental health. We collect child i's inputs in development period t in a vector $\left(\Theta^p_{it}, \Theta^h_{it}\right)$. Following the literature, our production function will be estimated in

[8] The annual separation rate of mothers in the sample who do not experience abuse is 0.005.

log form, so for notational simplicity we use θ_{it}^k as short-hand for $\ln \Theta_{it}^k$. As noted, the skills and the inputs are latent and we use $\boldsymbol{\theta}_{it}$ to denote the latent vector $\left(\theta_{it}^c, \theta_{it}^e, \theta_{it}^p, \theta_{it}^h\right)$. We further use $\boldsymbol{\theta}_i$ without time subscript to denote child i's full path of latent skills and inputs.

The data timeline Figure A.2 in Appendix A indicates the timing of the skill measurement and of the inputs. The three blue block segments depict the three development periods that are the focus of our analysis. For each development period $t = 1, 2, 3$, there are measures of skills at the start of that period $(\theta_{it}^c, \theta_{it}^e)$, as well as inputs pertaining to that period $\left(\theta_{it}^p, \theta_{it}^h\right)$. At the end of third development period, the terminal skills $\left(\theta_{i,4}^c, \theta_{i,4}^e\right)$ are measured.

Skill Measurements

The data contains a range of measures of cognitive skills over the sample period. The earliest measures that we use come from the Denver Developmental Screening Test (DDST) which includes four different categories: fine motor skills, gross motor skills, communication and social skills (Frankenburg and Dodds, 1967). These are measured when the child is aged 6 months old where, at this stage of childhood, they are considered cognitive skills (Rubio-Codina et al., 2016). These thus make up the measurements of the child's "initial" ($t = 1$) cognitive skills. At subsequent measurement points, the data further includes age-appropriate versions of MacArthur-Bates Communicative Development Inventories (CDIs). We therefore supplement the set of DDST cognitive skill measures with these additional measures that include vocabulary, grammar, and language and numbers scores (Fenson et al., 2007).

The data similarly contains a range of measures of socio-emotional skills. Initially, there is a battery of questions from the Carey Infant Temperament (CIT) questionnaire measuring activity, rhythmicity, approach, adaptability, intensity, mood, persistence, distractibility, and threshold score (Carey and McDevitt, 1977). We use the CIT measures for $t = 1, 2$. Later, the data further includes measures from the Emotionality Activity Sociability (EAS) Temperament Survey used to assess temperament in children. The EAS contains scores in specific domains including emotionality, activity and sociability (Bould et al., 2013). The EAS domain scores are used at $t = 3, 4$.

Parental Investment and Mother's Mental Health

The ALSPAC data also provides rich information on the study children's home environments, in particular regarding investments that parents make in their children. We use three measures of parental investments that are available in each of the three development periods, including: (i) a "parenting" score, (ii) an "activity" score and (iii) a "home" score, where the construction of each score depends on activities that are age-appropriate for the child. The parenting score is an index constructed based on the mother's report of how often she engages in a specific set of activities with her child including playing with the child, singing to child, showing the child picture books plays with toys together, cuddling the child, physically playing with the child, taking the child for walk and teaching the child, with some questions changing over time to reflect the aging of the child. The activity score is similarly an index constructed based on activities, but focusing on activities outside of the home, including the number of times the child is taken to the local shops, to a department store, to the supermarket, to the the park, and to visit friends and family. Finally, the home score is an index constructed on the basis of the items that the child has at home including cuddly toys, push/pull toys, co-ordination toys, a walker, a baby bouncer, number of books, with some items changing over time to reflect the aging of the child.

Our measures mother's mental health include the score on the Edinburgh Postnatal Depression Scale (EPDS) (Cox and Holden, 2003) which is standard instrument used to screen for symptoms of postnatal depression in new mothers. We further include the Crown Crisp Experiential Index (CCEI) (Crown and Crisp, 1979) used with new mothers to assess psychological distress, with subscores for anxiety, depression and somatic symptoms.

2.4 Measurement System

As skills and inputs are latent factors, the observed variables outlined above form part of a measurement system. Comparability of the latent factors across time periods requires additional restrictions on the measures (Agostinelli and Wiswall, 2016; Freyberger, 2025). A key feature of the ALSPAC data that allows us to address this issue is that we observe multiple measures of skills and inputs in each period, and critically, at least one measure for each latent factor that is repeated across all development periods.

Formally, for each latent factor θ_{it}^k there are multiple measures. The m'th measure of θ_{it}^k is denoted z_{itm}^k. We assume a log-linear measurement system between the latent skills/inputs and the observed measures whereby,

$$z_{itm}^k = \mu_{tm}^k + \lambda_{tm}^k \theta_{it}^k + \varepsilon_{itm}^k, \text{ for } k \in \{c, e, p, h\}, \tag{1}$$

where μ_{tm}^k and λ_{tm}^k are the location and scale parameters for the m'th measure at time t. The term ε_{itm}^k is a mean-zero measurement error, assumed to be independent across factors, time and measures, and normally distributed with variance σ_{ktm}^2. We normalize λ_{t1}^k equal to unity and μ_{t1}^k equal to zero for the first repeat observable measure of each latent factor, thereby fixing its scale. For the two skills, the repeat measures that we use are the DDST social skill score and the CIT mood score respectively.[9] For parental investment we use the activity score and for mother's mental health we use the EPDS score. Finally, we note that we use a "dedicated" measurement system, where each measure loads only onto a single factor. Moreover we have at least three measures that load onto each factor (Cunha et al., 2010).

Following Aucejo and James (2021) we will adopt a two-step estimation approach for our empirical analysis where the first step involves estimating the measurement system (1) and along with a flexible specification for the joint distribution of latent factors. The unconditional joint density of log skills and inputs, which we can denote $q(\boldsymbol{\theta}_i)$, is specified as a mixture of multivariate normal distributions.[10] We use maximum likelihood to estimate the measurement system (1) and the mixture distribution.

The full set of estimated parameters for the measurement system (1) is given in Table B.1 - B.4 in Appendix B. For the cognitive skills (Table B.1) the Denver DDST scores

[9]For $t = 3, 4$ we move the normalization for the socio-emotional skill over from CIT mood to the EAS emotionality: both indices broad aspects of affective temperament, reflecting the general tendency to display emotional tone.

[10]That is, we specify the density $q(\boldsymbol{\theta}_i)$ as given by $\sum_{d=1}^{D} \tau_d \cdot \phi(\boldsymbol{\pi}_d, \boldsymbol{\Omega}_d)$ with $\sum_{d=1}^{D} \tau_d = 1$, where $\phi(\boldsymbol{\pi}_d, \boldsymbol{\Omega}_d)$ is the probability density function of a multivariate normal distribution with means vector $\boldsymbol{\pi}_d$ and full variance-covariance matrix $\boldsymbol{\Omega}_d$. τ_d is the component weight for mixture component d. In the estimation we use a mixture distribution with $D = 4$ components. The parameters of the estimated mixture distribution are available on request.

in particular have consistently high signal-to-noise ratios. For the socio-emotional skills (Table B.2), the CIT scores used at $t = 1, 2$ vary in how strongly they reflect the latent skill and the same applies to the EAS scores used at $t = 3, 4$. In general, the scores for mood, adaptability and emotionality have consistently high signal-to-noise ratios. For parental investments (Table B.3), the three measures used in each period – the parenting, the activity and the home scores – show similar strengths in how they reflect the latent input. Similarly, for mother's mental health (Table B.4), the four measures used in each period – the EPDS, the anxiety, the somatic and the depression scores – are all strongly reflecting the latent health.

2.5 Association Between IPV Exposure and Skill Development

The measurement system (1) is entirely descriptive and separated from the specification of the skill production function and, critically, also from the observed IPV incidence. This allows us to use the estimated measurement system to generate individually estimated values of the latent skills which we, in turn, can relate to the observed exposure to IPV for a descriptive analysis. Specifically, we can back out classical Bartlett factor scores (Grice, 2001).[11]

Table B.5 in Appendix B highlights that each skill is highly correlated over time and, within each period, the two skills are also positively correlated. Moreover, as noted above, the normalization in eq. (1) based on a repeated measure makes the latent factors, in principle, comparable over time and Table B.5 indicates that each skill exhibits variation that is mildly increasing in age with the terminal skills ($t = 4$ at 52 months of age) exhibiting approximately unit variance. Hence, in the following we will interpret a skill unit as (approximately) a standard deviation.

Having obtained the skill factor scores as estimates of each child's skills at each point in time we can describe their dynamic relationships to IPV exposure. A natural starting point is to relate child i's skill level at time t to an indicator for any IPV exposure

[11]Write the measurement system (1) succinctly in matrix form as $\boldsymbol{z}_i = \boldsymbol{\mu} + \boldsymbol{\Lambda}\boldsymbol{\theta}_i + \boldsymbol{\varepsilon}_i$, where $\boldsymbol{z}_i$ is the vector of all observed measures for individual i, $\boldsymbol{\mu}$ is the vector of all measurement constants, $\boldsymbol{\Lambda}$ is the matrix with the factor loadings, and $\boldsymbol{\varepsilon}_i$ is the vector of individual i's measurement error terms. The Bartlett factor scores for individual i are then given by $\widetilde{\boldsymbol{\theta}}_i = \left(\widetilde{\boldsymbol{\Lambda}}'\widetilde{\boldsymbol{\Sigma}}_\varepsilon^{-1}\widetilde{\boldsymbol{\Lambda}}\right)^{-1}\widetilde{\boldsymbol{\Lambda}}'\widetilde{\boldsymbol{\Sigma}}_\varepsilon^{-1}(\boldsymbol{z}_i - \boldsymbol{\mu})$ where $\widetilde{\boldsymbol{\Sigma}}_\varepsilon$ is the diagonal matrix of estimated measurement error variances.

occurring up to that time whilst controlling for their corresponding initial skill and for baseline characteristics. This allows us to describe if the skill development of children who are exposed to IPV fall behind that of otherwise identical children. Thus we can estimate the following equation by OLS,

$$\widetilde{\theta}_{it}^{k} = \alpha_t^k + \beta_t^k \widetilde{\theta}_{i,1}^{k} + \phi_t^k IPVby_{it} + \boldsymbol{x}_i' \boldsymbol{\gamma}_t^k + \epsilon_{it}^k, \tag{2}$$

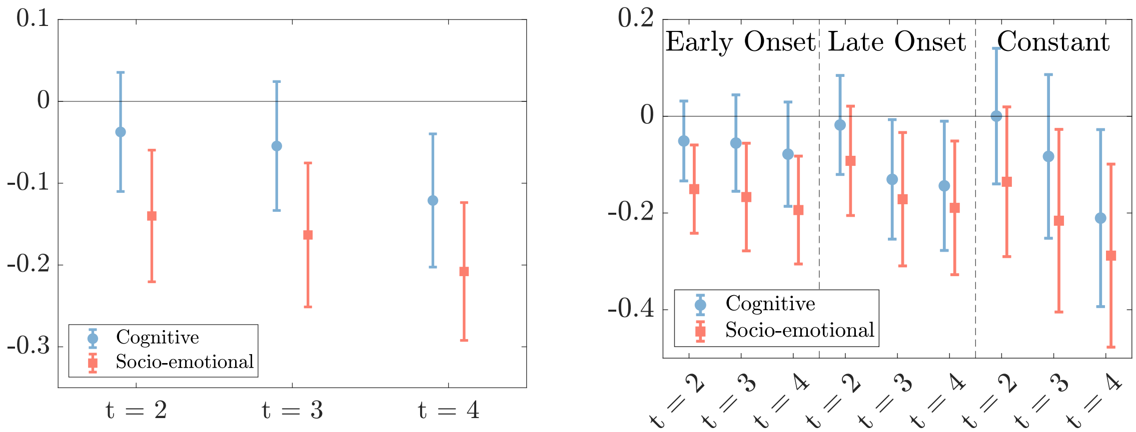
where $IPVby_{it}$ is a binary indicator for any observed (post-birth) IPV by time t and $\boldsymbol{x}_i$ is the vector of baseline characteristics.

The left panel of Figure 2 plots the estimated ϕ_t^k for each skill $k = c, e$ and time $t = 2, 3, 4$. The figure indicates that any IPV exposure by time t make the skills of the affected child fall behind the skills of otherwise similar children. This is particularly stark in the case of socio-emotional skills where the association between IPV exposure and skill deficit is both strong and evident from the first post-initial skill measurement point ($t = 2$ at 24 months of age). For the cognitive skills, the association with IPV exposure is less strong in general, but grows over time so that, by time $t = 4$ (at 52 months of age), any prior IPV exposure is strongly associated with a skill deficit compared to other children with the same initial skill level and baseline characteristics. In terms of magnitude, recalling that a skill unit (approximately) corresponds to a standard deviation, the estimates indicate that children exposed to IPV develop a skill deficit by, on average, about a fifth of a standard deviation over the first four years of life, aligning well with the pilot study by Anderberg and Moroni (2020) using the same ALSPAC data.

The specification in eq. (2) did not consider neither the finer timing of prior IPV exposure nor its duration. To refine the analysis we can partition the set of possible IPV paths. With three development periods, there are $2^3 = 8$ possible paths in total which we partition into four categories: (i) "Never IPV": $\boldsymbol{q}_i = (0, 0, 0)$ for $t = 1, 2, 3$, (ii) "Early Onset IPV": $q_{i,1} = 1$ but $\boldsymbol{q}_i \neq (1, 1, 1)$ (not "constant"), (iii) "Late Onset IPV": $q_{i,1} = 0$ but $\boldsymbol{q}_i \neq (0, 0, 0)$ (not "never"), and (iv) "Constant IPV": $\boldsymbol{q}_i = (1, 1, 1)$. Defining paths this way allows us to explore two key descriptive questions. First, do skill deficits only emerge *after* IPV has occurred? Do skill deficits grow larger if the IPV exposure *persists*? To do so we re-run eq. (2), replacing the $IPVby_{it}$ with dummies for IPV paths categories (ii)-(iv), leaving (i) "never IPV" as reference category. The results are presented in the

Figure 2: Association Between Skills and IPV Exposure

(a) Any IPV Exposure by t (b) IPV Path Category



Notes: The left panel shows the ϕ_t^k-coefficients from estimating (2) by OLS, where $\widetilde{\theta}_{it}^k$ is the (Bartlett) factor score for cognitive skills ($k = c$) and socio-emotional skills ($k = e$) at time $t = 1, 2, 3, 4$ and where the independent variable is an indicator for child i having had any IPV exposure by time t. The right panel shows the $\phi_{j,t}^k$-coefficients from estimating (2) by OLS where where the independent variables are a set of dummies for IPV path category. Children in the (i) "never IPV" category have the IPV path $\boldsymbol{q}_i = (0, 0, 0)$, (ii) "early onset" category have $q_{i,1} = 1$ but $\boldsymbol{q}_i \neq (1, 1, 1)$ (not "constant"), (iii) "late onset" category have $q_{i,1} = 0$ but $\boldsymbol{q}_i \neq (0, 0, 0)$ (not "never"), (iv) "constant IPV" category have the IPV path $\boldsymbol{q}_i = (1, 1, 1)$. The "never IPV" is the omitted reference category. The error bars indicate 95% confidence intervals.

right panel of Figure 2.

For cognitive skills, IPV paths with "early onset" are associated with relative minor and not statistically significant skill deficits. This contrasts the association with socio-emotional skills that react early and sizeably. This finding is somewhat surprising in light of the literature (e.g., Cunha and Heckman 2008; Attanasio et al. 2020) which has found cognitive skills to be most sensitive to early shocks with socio-emotional skill deficits developing more gradually. Our description analysis instead indicate that IPV exposure before age two causes immediate, large socio-emotional deficits.

The cases with "late onset" of IPV allow us to check that IPV exposure is not associated with skill deficits prior to the exposure occurring. These are cases where the mother first reports IPV when the child is either 33 or 47 months of age. In principle therefore, when skills are measured at $t = 2$ (when the child is 24 months of age) IPV has not yet occurred and we should not see any association between this IPV path category and skills at this time.[12] For cognitive skills we indeed see no skill deficit at $t = 2$, whereas we do

[12]In about two thirds of cases with "late onset" of IPV, the first abuse is reported by the mother when

see (just) significant deficits at $t = 3, 4$. For socio-emotional skills, the estimated skill deficit at $t = 2$ is comparatively smaller at point estimate and not statistically significant, whereas at $t = 3, 4$ the deficits are both larger and statistically significant.

Finally for the cases with "constant" IPV exposure the statistical precision is low, reflecting that there are less than 100 such children in the data. Nevertheless, for both skills, the skill deficits grow over time and become sizeable and statistically significant by $t = 4$ for the cognitive skills and by $t = 3, 4$ for the socio-emotional skills. Note that, at $t = 2$ children with "early onset" and "constant" exposure will both have experienced a first development period with IPV exposure and should therefore exhibit equal-sized skill deficits for each skill. As is easily seen from Figure 2, this is not rejected by the data.

Differences in the timing of onset of IPV is of particular interest as this provides important variation for our empirical model. It is then of interest to explore whether the timing variation among those with some IPV exposure is, seemingly, as good as random. To this end, we can test if a child's IPV path category – "never", "early", "late" or "constant" – is unrelated to their observable baseline characteristics. Figure A.3 plots the means (with 95% confidence intervals) for each baseline characteristic across the four path categories. The figure shows that the only characteristic for which there are statistically significant differences is parity: children with no IPV exposure are more likely to be first-born. There are no statistically significant differences – for any baseline characteristic – across the three IPV path categories with positive exposure, suggesting the categories are balanced on observables.[13]

Figure 2 above illustrates how children exposed to IPV have a slower skill development compared to children with no such exposure but who are otherwise identical in terms of initial skills and baseline characteristics. The figure does not however show how they compare in terms of initial skills. Figure A.4 in Appendix A illustrates how the children

the child is aged 33 months. Since mothers are asked about abuse over the past 12 months, there is a potential overlap between 21 and 24 months where the first occurrence of abuse happened before the skill measurement.

[13]The figure omits partnership status as baseline characteristic. This characteristic is not balanced: mothers who indicate experiencing abuse in the first development period ($q_{i,1} = 1$, that is, at any point between 32 weeks of pregnancy and 21 months post-birth) are six percentage points less likely to live with a partner at baseline. This difference can be shown to be entirely driven by mothers who indicate abuse at the 8-month survey, not by mothers who first report abuse at the 21-month survey (see Figure A.2 in Appendix A). Hence this imbalance reflects early separations.

who will be exposed to IPV over their pre-school years are very similar in initial skills (measured at six months of age, $t = 1$) to those children who won't have any such exposure. Specifically, Figure A.4 shows how children – for each IPV path category – are distributed across skill quartiles. The two upper panels show that, for the initial skills, children with no IPV exposure ("never-IPV") are effectively uniformly distributed across the bottom, lower-middle, upper-middle and top skill quartiles. Correspondingly, the children who will experience some IPV exposure – either with "early onset", "late onset" or "constant" IPV – show no distinct pattern of over-representation in the lower skill quartiles and/or under-represented in the upper quartiles.[14] To contrast this absence of differences in initial skills, the lower panels in Figure A.4 present the corresponding distributions for the terminal skills (measured at 52 months, $t = 4$). This highlights that children in all three path categories of IPV exposure are over-represented in the bottom quartile and under-represented in the top quartile, for both skills. Correspondingly, the never-exposed children are now systematically over-represented at the top end in each skill distribution and under-represented at the bottom end. In terms of implied percentile deficit sizes, by the end of the pre-school period, the IPV-exposed children are behind their non-exposed peers by, on average, 2-7 percentiles in the distributions of cognitive and socio-emotional skills respectively.

The descriptive analysis in this section has thus demonstrated that the children observed in the ALSPAC data to have been exposed to IPV over their pre-school period did not differ systematically from the non-exposed children, neither in terms of initial skills nor in terms of baseline characteristics (except for having a lower likelihood of being first-born). This offers reassurance that the dynamic patterns of emergence of skill deficits highlighted in Figure 2 reflect the IPV exposure and its timing.

3 Model of Skill Formation

To describe the formation and evolution of cognitive and socio-emotional skills throughout early childhood, including different mechanisms through which exposure to IPV affects

[14] ANOVA tests of means differences in *initial* skill factor scores, $\widetilde{\theta}^c_{i,1}$ and $\widetilde{\theta}^e_{i,1}$, across the four path categories have p-values of 0.448 and 0.120 respectively. This strongly contrasts the p-values for corresponding tests on the *terminal* skill factor scores, $\widetilde{\theta}^c_{i,4}$ and $\widetilde{\theta}^e_{i,4}$, which are 0.047 and <0.001 respectively.

the skill development process, we use a dynamic latent factor model building on the seminal contribution of Cunha et al. (2010). The latent factor model is a natural choice for our setting because it allows us to fully utilise the richness of the ALSPAC data, containing multiple measures of cognitive and socio-emotional skills in each development period. However, the model is also flexible as it allows for skills to be self-producing, while including cross-effects between skills, and dynamic complementarities with respect to the inputs. These features are important for our setting because they allow us to understand how IPV exposure in early childhood has long-term consequences for the development of future skills, and to quantify the relative contributions of the mechanisms that are driving these effects. In developing our model we make a number of key specification choices that also reflect to how the literature has evolved since the seminal contribution by Cunha et al. (2010).

First, we estimate a production technology for skill formation – with two skills and two distinct inputs – that takes a transcendental logarithmic ("translog") functional form, originally proposed by Christensen et al. (1973). With the exception of Agostinelli and Wiswall (2025), Agostinelli and Wiswall (2016), Del Bono et al. (2022) and Moroni et al. (2025), translog technologies have not been widely considered in the skill development literature. However, a distinct benefit of the translog technology is that it removes the restrictive substitution and transformation patterns imposed by constant elasticities of substitution (CES) technologies.[15] In addition, Del Bono et al. (2022) show that for translog technologies, properly anchored treatment effects remain invariant to location and scale normalisations of the underlying measures, while the same property does not hold for CES technologies. These features make the translog technology suitable for our context.

Second, within the translog production technologies we relax the assumption of constant returns to scale and include a linear total factor productivity (TFP) equation.[16] The TFP captures factors that affect skill development other than the inputs themselves. These include birth- and baseline characteristics, but importantly for our setting, it also provides a *direct* mechanism through which exposure to IPV can affect the skill develop-

[15] Attanasio et al. (2017) and Aucejo and James (2021) relax this restriction by estimating nested-CES production technologies.

[16] Agostinelli and Wiswall (2016) and Freyberger (2025) outline the location and scale restrictions required in order to identify a TFP term.

ment.

Third, building on Attanasio et al. (2020) we model the parental investment and mother's mental health inputs as linear reduced-form equations.[17] The equations for parental investment and mother's mental health inputs also serve an additional function within the model. In particular, by allowing IPV to directly effect parental investment and mother's mental health, these represent an *indirect* mechanisms through which IPV affects the skill development process.

Finally, we build on the two-step estimation procedure introduced by Aucejo and James (2021) and jointly estimate the full model for all development periods.

3.1 Skill Production Technologies

We assume that next period cognitive ($k = c$) and socio-emotional ($k = e$) skills develop via a translog production technology that depends on current skills and current inputs

$$\theta^k_{i,t+1} = A^k_t(q_{it}, \boldsymbol{x}_i) + \boldsymbol{\theta}'_{it}\boldsymbol{\gamma}^k_t + \boldsymbol{\theta}'_{it}\boldsymbol{\Gamma}^k_t\boldsymbol{\theta}_{it} + \eta^k_{it}, \text{ for } k = c, e, \text{ and } t = 1, 2, 3, \quad (3)$$

where $A^k_t(\cdot)$ is a total factor productivity (TFP) that takes the form

$$A^k_t(q_{it}, \boldsymbol{x}_i) = \alpha^k_{0,t} + \alpha^k_{q,t} q_{it} + \boldsymbol{x}'_i\boldsymbol{\alpha}^k_{x,t}. \quad (4)$$

The TFP eq. (4) includes q_{it}. This captures the direct effect of current IPV exposure on next period skills. The TFP further depends on the mother and child baseline characteristics, $\boldsymbol{x}_i$. η^k_{it} is an unobserved skill shock. In eq. (3), the vector $\boldsymbol{\gamma}^k_t$ contains the four linear terms $\gamma^k_{j,t}$ for $j = c, e, p, h$ whilst $\boldsymbol{\Gamma}^k_t$ is a (triangular) matrix that contains the ten quadratic- and cross-terms $\gamma^k_{jj',t}$ for $j, j' = c, e, p, h$. The initial skills of each individual i are modelled as linear functions of their baseline characteristics, $\theta^k_{i,1} = \alpha^k_{0,0} + \boldsymbol{x}'_i\boldsymbol{\alpha}^k_{x,0} + \eta^k_{i,1}$, for $k = c, e$.

[17] Specifically for investments, Attanasio et al. (2020) note that in the absence of additional information on parental beliefs about the returns on their investments or the assumption that parents have perfect information regarding the structure of the production technologies, this approach provides a parsimonious way to model these inputs that is consistent with a more general structural model.

3.2 Parental Investment and Mother's Mental Health

As we do not have information on parental beliefs regarding the returns of their investments, and want to avoid making strong assumptions about parents knowledge of the production technologies, we follow Attanasio et al. (2020) and specify a reduced-form equation for parental investments. We similarly specify a reduced form equation for mother's mental health. The two reduced-form equations are specified, respectively, as

$$\theta_{it}^{p} = \delta_{t}^{p} + \delta_{c,t}^{p}\theta_{it}^{c} + \delta_{e,t}^{p}\theta_{it}^{e} + \delta_{h,t}^{p}\theta_{i,t-1}^{h} + \boldsymbol{x}_{i}'\boldsymbol{\delta}_{x,t}^{p} + \delta_{q,t}^{p}q_{it} + \boldsymbol{w}_{it}'\boldsymbol{\delta}_{w,t}^{p} + \eta_{it}^{p}, \tag{5}$$

and

$$\theta_{it}^{h} = \delta_{t}^{h} + \delta_{c,t}^{h}\theta_{it}^{c} + \delta_{e,t}^{h}\theta_{it}^{e} + \delta_{p,t}^{h}\theta_{i,t-1}^{p} + \boldsymbol{x}_{i}'\boldsymbol{\delta}_{x,t}^{h} + \delta_{q,t}^{h}q_{it} + \boldsymbol{w}_{it}'\boldsymbol{\delta}_{w,t}^{h} + \eta_{it}^{h}. \tag{6}$$

Eq. (5) models the parental investment θ_{it}^{p} as depending on the child's current skills, θ_{it}^{c} and θ_{it}^{e}, on the baseline characteristics, $\boldsymbol{x}_i$, and on the IPV incidence q_{it}. Eq. (6) models the mother's mental health as depending on the same factors. Further, (5) and (6) also allow for cross-effects between the inputs by making each depend on the previous period's value of the other. The terms η_{it}^{p} and η_{it}^{h} represent random shocks.

Eqs. (5) and (6) capture key mechanisms through which IPV incidence, q_{it}, may indirectly affect child skill development. Firstly, IPV incidence may affect skill development indirectly by affecting both parental investment and mother's mental health (Cerulli et al., 2011), both of which are inputs in the skill production technologies. Secondly, IPV exposure may indirectly dynamically affect child skill development further through cross-effects between parental investment and mothers mental health. For instance, the level of future parental investment may be affected by IPV through its effect on current mother's mental health.

A concern with modelling the inputs, θ_{it}^{p} and θ_{it}^{h}, in a reduced-form way is that shocks to skill development, η_{it}^{c} and η_{it}^{e}, could be correlated with shocks to parental investment and mother's mental health, η_{it}^{p} and η_{it}^{h}. This is plausible if, for example, parents consider shocks to their child's skills when they take their investment decisions. If this is true, then the inputs are endogenous. To address this concern we follow Attanasio et al. (2020) and use a control function approach. To this end, we include two further variables in eqs. (5) and (6) (but exclude them from the production function eqs. (3) and (4)).

These will serve as instruments. The first variable used is an income measure. As we want this effective resource measure to shift parental investments in particular – notably the availability of child-related items in the household and child-related activities – but not otherwise directly affect the child's skill development, we use a measure of household earnings potential calculated as the total hourly pay predicted from the parents' occupations and the current national average pay in those occupations by gender.[18] The second variable used is an index of life events – the counts of events out of a possible twelve – that the mother reports to have occurred. The twelve events were selected from an events inventory to be plausibly exogenous and likely to have put a mental strain on the mother without having a direct effect on the child's skill development.[19]

As a check that the instruments relate to the (latent) inputs we can again use the Bartlett factor scores and estimate simplified versions of (5) and (6). For each input $k = p, h$ and development period $t = 1, 2, 3$ we can regress $\widetilde{\theta}_{it}^{k}$ on $w_{i,t}^{y}$, $w_{i,t}^{l}$ and $\boldsymbol{x}_i$. The results from these diagnostic regressions are presented in Figure A.5 in Appendix A We would expect better resources ($w_{i,t}^{y}$) to elevate both inputs and the index of (adverse) life events ($w_{i,t}^{l}$) to have the opposite effect. For parental investments, the estimates indeed indicate positive effects of resources, but the estimates are also quite imprecise. In contrast, the estimates for the effect of adverse life events on parental investment are precise but small. For mother's mental health, the estimates again indicate positive but imprecise effects of resources. However, the estimated effects of adverse life events are both strongly negative and precise. This indicates that the instruments do affect the inputs as expected, but with a slight concern that neither instrument has a strong *and* precise impact on parental investments. As both inputs are expected to positively contribute to skill accumulation we would expect the same sign pattern if we relate $w_{i,t}^{y}$ and $w_{i,t}^{l}$ to child skills, $\widetilde{\theta}_{i,t+1}^{k}$ for $k = c, e$. This holds up for the life events index $w_{i,t}^{l}$ which shows distinctly negative and precisely estimated effects on both skills, socio-emotional skills in particular. Given the resource measure's relatively weaker relationship of the resource measure $w_{i,t}^{y}$ to the inputs, unexpectedly its estimated relationships to the skills, though generally of

[18] The average hourly pay by occupation and gender at the national level were calculated from the UK Labour Force Survey.

[19] The life events included are death/illness of relative or friend; arguments with family or friends; unexpected bleeding or miscarriage; home being burgled; self/partner having problems at work; partner being ill/losing job/going away/being in trouble with law; experiencing an income reduction.

the expected sign, are also imprecise.

To account for possible endogeneity, in our full estimation we follow Attanasio et al. (2020) as use the residuals from (5) and (6) as additional regressors in the TFP eq. (4). Exogeneity of the inputs would imply coefficients on the residual terms equal to zero. We test this and show that exogeneity cannot be rejected. In line with this also find that the estimated parameters of the production function are largely unaffected by whether we account for endogeneity or not.

3.3 Estimation Procedure

To estimate the model we follow the two-step estimation procedure of Aucejo and James (2021). This procedure is preferable for our setting as it, by only placing structure on the joint density of the latent factors, is able to accommodate binary and discrete child characteristics, such as exposure to IPV.[20] The estimation takes place in two steps.

The first step estimates the parameters of the measurement system in eq. (1) and recovers the joint distribution of latent skills and inputs. This step was outlined above and the results were presented in Section 2.4. This first step of the estimation recovers not only the unconditional distribution of the latent factors, $q(\boldsymbol{\theta}_i)$ (see Section 2.4 above) but, by recovering the parameters of the measurement system, it also recovers their distribution conditional on the individually observable measures, $q(\boldsymbol{\theta}_i \mid \boldsymbol{z}_i)$.

The second step estimates the parameters of the skill production function (3) and (4), the investment eq. (5), and the mother's mental health eq. (6). The skill production function links next period skills to current skills and inputs, as well as to baseline characteristics and current IPV exposure. Specifically, it implies marginal conditional distributions of $\theta^k_{i,t+1}$ for skill $k = c, e$ which we denote $f\left(\theta^k_{i,t+1} | \theta^c_{it}, \theta^e_{it}, \theta^p_{it}, \theta^h_{it}, \boldsymbol{x}_i, q_{it}\right)$. Similarly, (5) and (6) imply marginal conditional distributions for each input θ^k_{it}, $k = p, h$ which we can denote $f\left(\theta^k_{it} | \theta^c_{it}, \theta^e_{it}, \theta^p_{i,t-1}, \theta^h_{i,t-1}, \boldsymbol{x}_i, q_{it}\right)$. The conditional joint probability of skill and input path $\boldsymbol{q}_i$ for individual i can then be expressed as the forward recursive

[20] An alternative approach is the estimation procedure introduced by Attanasio et al. (2020). Implementing their estimation procedure would however require fitting a mixture distribution to binary and discrete characteristics, including the child's path of IPV exposure.

product of the marginal conditional distributions over time,

$$F\left(\boldsymbol{\theta}_i|\boldsymbol{x}_i,\boldsymbol{q}_i\right)=\prod_t\prod_{k\in\{c,e,p,h\}}f\left(\theta_{it}^k|\cdot,\boldsymbol{x}_i,q_{it}\right). \tag{7}$$

Let $\boldsymbol{\Psi}$ denote the vector of all parameters in the skill production functions (3) and (4), the input eq. (5) and (6) (including error variances). Aucejo and James (2021) show that the overall log likelihood function can be partitioned into two additive components, only one of which involve the parameters of the production function. Following the same logic (see Appendix C), we can estimate the parameters $\boldsymbol{\Psi}$ by maximizing the following log likelihood component

$$\ln\mathcal{L}(\boldsymbol{\Psi})=\sum_{i=1}^{N}\ln\left[\int_{\boldsymbol{\theta}_i}F\left(\boldsymbol{\theta}_i,|\boldsymbol{x}_i,\boldsymbol{q}_i\right)q(\boldsymbol{\theta}_i\mid\boldsymbol{z}_i)\,d\boldsymbol{\theta}_i\right], \tag{8}$$

which uses that the distribution of latent factors conditional on the individual's observed measures, $q(\boldsymbol{\theta}_i\mid\boldsymbol{z}_i)$, was characterized by the first step of the estimation. This is used to evaluate the integral in eq. (8) by simulation, specifically, by taking R draws of possible latent factors, $\boldsymbol{\theta}_i$, for each child i from $q(\boldsymbol{\theta}_i|\boldsymbol{z}_i)$.[21] To obtain standard errors and confidence intervals for all parameter estimates, we compute 200 bootstrap replications over both estimation steps.

4 Main Estimation Results

This section presents our core estimates. We start by discussing the equations for parental investment and mother's mental health before presenting features of the production function. Finally we consider how well our model captures the descriptive dynamic relationship between skills and IPV from Section 2.

[21]To reduce simulation errors we use $R=10$ draws for each child.

4.1 Parental Investment and Mother's Mental Health

Table 2 reports estimates of the parental investment eq. (5) and mother's mental health eq. (6) for each development period, focusing on the effects of IPV, skills and cross-input effects. Panel (a) in Table 2 shows the effect of current IPV incidence. The estimates point to distinctly different effects across the two inputs, with effects on current parental investments that are neither sizeable nor statistically significant, but a substantial negative and significant effect on mother's mental health.

Table 2: Parental Investments and Mother's Mental Health

	Parental investments (θ_t^p)			Mother's mental health (θ_t^h)		
	$t=1$	$t=2$	$t=3$	$t=1$	$t=2$	$t=3$
a) IPV						
IPV (q_{it})	-0.06	-0.00	0.01	-0.57	-0.65	-0.55
	[-0.13, 0.00]	[-0.05, 0.05]	[-0.04, 0.05]	[-0.65, -0.48]	[-0.75, -0.54]	[-0.66, -0.44]
b) Skills and inputs						
Cognitive skills (θ_{it}^c)	0.46	-0.14	-0.20	0.05	-0.09	-0.03
	[0.33, 0.58]	[-0.23, -0.05]	[-0.28, -0.13]	[-0.01, 0.11]	[-0.17, -0.01]	[-0.10, 0.05]
Socio-em. skills (θ_{it}^e)	0.04	0.01	-0.03	0.24	0.23	0.20
	[-0.02, 0.10]	[-0.05, 0.06]	[-0.08, 0.02]	[0.20, 0.29]	[0.18, 0.28]	[0.15, 0.25]
Mother's m.-h. ($\theta_{i,t-1}^h$)	-	0.84	0.71	-	-	-
		[0.69, 0.99]	[0.53, 0.89]			
Parental inv. ($\theta_{i,t-1}^p$)	-	-	-	-	0.22	0.18
					[0.11, 0.33]	[0.07, 0.29]
c) Income, life events						
Current Inc. (w_{it}^y)	0.11	0.02	0.01	0.01	0.13	0.15
	[0.07, 0.16]	[-0.00, 0.04]	[-0.02, 0.03]	[-0.06, 0.09]	[0.05, 0.20]	[0.09, 0.22]
Life events (w_{it}^l)	0.00	-0.01	0.00	-0.09	-0.11	-0.11
	[-0.01, 0.01]	[-0.01, -0.00]	[-0.01, 0.01]	[-0.11, -0.08]	[-0.12, -0.10]	[-0.12, -0.09]

Notes: Notes: The table presents parameter estimates for the reduced-form eqs. (5) and (6) for parental investments and mother's mental health for each development period $t = 1, 2, 3$. For the full set of estimated coefficients, see Table B.7 in Appendix B. 90% confidence intervals in square brackets are computed using 200 bootstrap replications.

Panel (b) considers the role of skills and (lagged) inputs. The early parental investment is boosted by the child's initial cognitive skills. Later on better (lagged) mother's mental health also significantly elevates parental investments. Mothers consistently enjoy better mental health when their children have higher levels of socio-emotional skills, and past parental investment also improve mother's mental health.[22]

[22]The full set of estimated parameters from (5) and (6), including the coefficients on the baseline characteristics are shown in Table B.7 in Appendix B. These show that e.g. high education is associated with more parental investments, whilst higher birth parity is associated with worse mental health.

Panel (c) reports the estimated coefficients on the two instrumental variables – current income and the index of adverse life events experienced by the mother in the past twelve months. The estimated effects are broadly in line with the diagnostic estimates noted above (see Figure A.5 in Appendix A) but are generally somewhat attenuated in comparison. Current income has mostly positive effects on both inputs, but the estimates are imprecise compared to the estimates for the life events index. The estimated effects of the life events strongly negative for mother's mental health but effectively zero for parental investments. Indeed, since the index is a count (out of twelve) of other adverse events experienced by the mother, the coefficients on the index and on IPV are directly comparable. The estimates suggest that the negative effect on the mother's mental health of experiencing IPV is about six times as large as the average effect of an events in the index, e.g. unexpected bleeding or miscarriage or death/illness of a relative or friend.

4.2 Skill Production Technologies

We now consider the skill production technologies. These determine the evolution of skills over time, allowing for complementarities between skills and inputs, and for direct and indirect effects of IPV. Whilst we report the full set of estimated parameters from eqs. (3) and (4) in Tables B.8, B.9, B.10 and B.11 in Appendix B, we focus here on the implied marginal effects on next period skills of each skill, input and of IPV. Two things are worth noting. First, since our variables are in log form, the reported marginal effects – which are based on the preferred specification with endogenous inputs – can be interpreted as elasticities. Second, the reported marginal effects are "total" derivatives/effects, that is the effects of current inputs and or IPV include effects via the inputs.[23] The estimated marginal effects are presented in Table 3 where panel (a) shows the effects on cognitive skills and panel (b) shows corresponding effects on socio-emotional skills.

The reported marginal effects exhibit features that are, in large, consistent with recent production technology estimates regarding the structure and dynamics of the skill accumulation process (Cunha et al., 2010; Attanasio et al., 2020; Aucejo and James, 2021).

[23] An increase in θ_{it}^{k} affects $\theta_{i,t+1}^{k'}$ not only directly but also through its effect on inputs θ_{it}^{p} and θ_{it}^{h} as reflected in eqs. (5) and (6). For IPV, the "marginal" effect is the difference between $q_{it} = 1$ and $q_{it} = 0$. See Appendix C for a full derivation of the marginal effects which have simple closed-form expressions and carry intuitive interpretation.

Table 3: Marginal Effects on Next-Period Skills

	Cognitive Skills ($\theta^c_{i,t+1}$)			Socio-Em. Skills ($\theta^e_{i,t+1}$)		
	$t=1$	$t=2$	$t=3$	$t=1$	$t=2$	$t=3$
a) Skills and inputs						
Cognitive skills (θ^c_{it})	0.51	1.05	0.77	0.19	-0.18	0.03
	[0.40, 0.62]	[0.94, 1.15]	[0.69, 0.85]	[0.13, 0.24]	[-0.31, -0.06]	[-0.03, 0.10]
Socio-em. skills (θ^e_{it})	0.05	-0.03	0.19	0.48	0.49	0.89
	[-0.00, 0.10]	[-0.09, 0.02]	[0.11, 0.26]	[0.41, 0.55]	[0.28, 0.69]	[0.78, 1.01]
Parental inv. (θ^p_{it})	0.34	-0.02	0.04	0.05	0.19	-0.01
	[0.23, 0.46]	[-0.11, 0.08]	[-0.05, 0.13]	[-0.07, 0.17]	[0.01, 0.37]	[-0.11, 0.09]
Mother's m.-h. (θ^h_{it})	-0.02	0.10	0.02	0.22	0.28	0.05
	[-0.08, 0.04]	[0.03, 0.16]	[-0.04, 0.08]	[0.15, 0.29]	[0.14, 0.41]	[-0.03, 0.12]
b) IPV						
IPV (q_{it})	-0.02	-0.07	-0.01	-0.16	-0.16	-0.05
	[-0.08, 0.03]	[-0.13, -0.01]	[-0.07, 0.05]	[-0.23, -0.08]	[-0.28, -0.03]	[-0.12, 0.01]

Notes: The table shows estimated marginal effects (elasticities) of current skills, inputs and IPV on each next period skill, by development period. The full derivation of the marginal effects are presented in Appendix B. The presented marginal effects use the estimated parameters presented in Tables B.7, B.8, B.9, B.10 and B.11 in Appendix B (using the preferred specification with endogenous inputs and control function approach). As the marginal effects are non-linear functions they are reported here for a child with median skills and inputs and median/mode baseline characteristics. 90% confidence intervals in square brackets are computed using 200 bootstrap replications.

For instance, both skills feature self-productivity at all ages with elasticities of next period skill with respect to current skill ranging from generally between 0.5 and unity. There is also some evidence of complementarities across skills. For instance, socio-emotional skills have either positive or insignificant effect on next period cognitive skills. For cognitive skills, the main positive input effect is from parental investments in the earliest development period. For socio-emotional skills in contrast, mother's mental health has a marked positive marginal effect, at least through the first two development periods.

From combining the insights from Tables 2 and 3, it follows that the likely most severe *indirect* effect of IPV exposure will be on socio-emotional skills via mother's mental health, particularly in the first two development periods (that is, up to age three). The total marginal effects of IPV reported in Table 3 of course also include the *direct* effects via the TFP. However, as shown in Tables B.10 and B.11 in Appendix B, the estimated coefficients on IPV in the TFP equations ($a^k_{q,t}$) are generally small, generally close to zero in magnitude, and never statistically significant, indicating that the indirect effects will be the dominant mechanisms. In line with this, Table 3 shows that the strongest marginal effects of IPV on next period skills are on socio-emotional skills in the first and second development period, with marginal effects that are both strongly significant and economically sizeable. Nevertheless, all estimated marginal effects of IPV exposure on next period skills are all negative at point estimate and half of the estimated IPV marginal effects also statistically significant at the 90% percent level.

The notion that a large share of the overall effect of IPV exposure on skill development occurs indirectly via inputs will be explored further in Section 5.1. In that section we will also consider the longer dynamic effects, e.g. the impact of IPV exposure in the first development period (before age 2) on skills not only at age 2, but also at ages 3 and 4. Such longer-run effects will occur through dynamic complementarities that serve to perpetuate the skill deficits that materialise due to early IPV exposure through its compounding effect over time. For instance, as early IPV exposure ($q_{i,1} = 1$) negatively affects the child's socio-emotional skills ($\theta^e_{i,2}$), it will also worsen the mother's next period mental health ($\theta^h_{i,2}$), and this in turn will negatively affect both future skill ($\theta^c_{i,3}$ and $\theta^e_{i,3}$) etc. Further, going beyond the marginal effects, dynamic complementarities generally imply that higher levels of current skills make other future inputs more effective. For instance, an early socio-emotional skill deficit due to IPV exposure may lower the effectiveness of future parental investment in the production of both skills.

Finally, we note that from Tables B.10 and B.11 in Appendix B that the coefficients on the residuals from the input equations are not statistically significant. The residuals from the mother's mental health equations are estimated to have fairly precise zero coefficients. Given the strength of the life events index in particular as an instrument for mental health, this indicates an absence of correlations between the mother's mental health shock η^h_{it} and the skill shocks, η^p_{it} and η^p_{it}. The coefficients on the residuals from the parental investment equations are non-negative – indicating potential reinforcing investments by parents – however, in line with the instruments being weaker for parental investments, the estimates here are also less precise. Despite the absence of strong evidence of endogeneity, we will use the model with endogenous inputs in describing the model fit and when performing decompositions and policy simulations.

4.3 Model Fit to IPV-Skills Dynamics

In Section 2 we used that the measurement system (1) is estimated entirely separably from the IPV data to provide a descriptive analysis of how cognitive and socio-emotional skills – estimated as Bartlett scores from the observable measures – were dynamically associated with IPV exposure. The analysis, illustrated in Figure 2, highlighted how the IPV-exposed children developed skill deficits relative to their otherwise observationally identical peers. Having now estimated our main structural model we can check that it captures this dynamic empirical association.

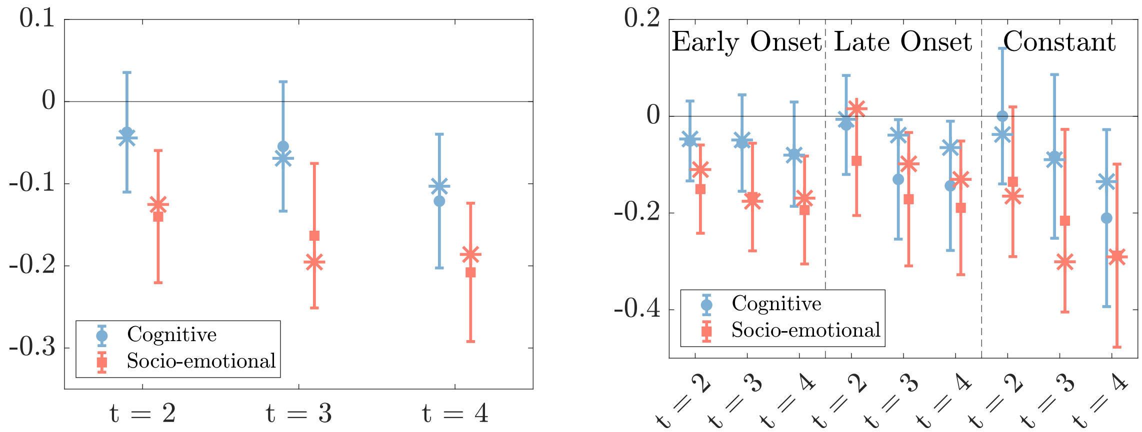
To do so we simulate the effect of IPV exposure on the skill development paths for a set of otherwise representative children – all endowed with median/mode baseline characteristics and median initial skills. Recall however that with three development periods, there are $2^3 = 8$ possible full IPV paths, all of which occurred in the ALSPAC data. To represent this, we generate a distribution of full IPV paths for our simulated population that closely aligns with the empirical one.[24] We then forward-simulate skills paths for all children and relate the implied skill deficits to IPV exposure in the same way as was done in Figure 2.

Figure 3 shows that our estimated model captures the dynamic association between child skills and IPV exposure well. The left panel super-imposes the model-simulated skills deficits – indicated by asterisks – of children exposed to IPV by time t relative to children without any such exposure onto the corresponding empirical association replicated from Figure 2 above. The figure shows that the model captures the core feature of an overall larger and more immediate association between IPV exposure and socio-emotional skills than for cognitive skills. It also shows how the model captures that skill deficits gradually increase over time. Moreover, the model closely replicates the magnitudes of the skill deficits and always well within the within the 90% confidence intervals of the corresponding empirical ones.

[24] Specifically, we generate simulated IPV paths using three probabilities, $\widetilde{q}^b = \Pr(q_{i,1} = 1)$, and for $t = 2, 3$, $\widetilde{q}^0 = \Pr(q_{it} = 1 | q_{i,t-1} = 0)$ and $\widetilde{q}^1 = \Pr(q_{it} = 1 | q_{i,t-1} = 1)$. We select the vector $\widetilde{\boldsymbol{q}} = \left(\widetilde{q}^b, \widetilde{q}^0, \widetilde{q}^1\right)$ so that the simulated distribution of full paths across the eight possible IPV paths aligns as closely to the empirical distribution as possible, giving us $\widetilde{\boldsymbol{q}} = (0.135, 0.031, 0.505)$. These three probabilities capture the IPV incidence and dynamics very closely, with the proportion of each possible full IPV path in the simulated population being within 1.2 percentage points of the corresponding proportion in the empirical population. Note that the difference $\widetilde{q}^1 - \widetilde{q}^0$ closely aligns with persistence of IPV highlighted in the right panel of Figure 1.

Figure 3: Model Fit to Association Between Skills and IPV Exposure

(a) Any IPV Exposure by t (b) IPV Path Category



Notes: The figure shows the fit of the model-simulated association between skills and IPV exposure – indicated by asterisks – to the corresponding empirical association replicated from Figure 2. The left panel compares the skills, at time $t = 2, 3, 4$, of children with some IPV exposure by time t to children without such exposure, but who are otherwise identical. In the ALSPAC data, this is achieved by controlling for initial skills and baseline characteristics (see Section 2). In the simulation, all paths are for children with median/mode baseline characteristics and initial skills. In total the simulation is for 10,000 children who are simulated onto IPV paths with a distribution that matches the empirical distribution. The right panel compares the skills, at time $t = 2, 3, 4$, of children with full IPV paths with some abuse exposure to otherwise identical children with paths without any abuse exposure. See Section 2 for a full description of the characterization of the empirical associations.

Similarly, the right panel super-imposes the simulated skills deficits for children exposed to categories of full IPV paths with some abuse relative to otherwise identical children with no abuse onto the corresponding empirical association replicated from Figure 2. Again, the figure shows that the model captures the core features well, e.g. the differences between the two skills. Note that the simulated data per construction will have two features holding by construction. First, for children with "late onset" of IPV, the simulated model will predict a zero skill deficit (bar simulation noise) at time $t = 2$ as these children are, at that stage, still identical to the no-exposure children. Second, also at $t = 2$, children with "early onset" and children with "constant" exposure have had the same early exposure to abuse and therefore exhibit the same skill deficits. As noted in Section 2, neither of these two features were rejected in the ALSPAC data.

5 Decomposing the IPV Effects

A key benefit to estimating the skill production functions is that it offers insights into *how* skill deficits emerge. For instance, do skill deficits emerge *directly* from IPV exposure effects or *indirectly* via inputs? It also provides insights into how the dynamics is shaped. For instance, are current skills deficits for children exposed to IPV due to *current* or *prior* exposure? And are there *critical periods*? Such insights can be useful for informing potentially mitigating interventions.

5.1 Decomposing Current and Prior Effects

To address some of the above questions, we will perform a decomposition exercise. Specifically, carrying forward the approach used in Section 4.3, we will continue to simulate IPV-induced skill deficits for otherwise representative children. For the current decomposition exercise we will consider only three full IPV paths, all starting with abuse in the first period but with varying duration of exposure to abuse: one, two or all three development periods – $\boldsymbol{q}_i \in \{(1,0,0),(1,1,0),(1,1,1)\}$ – each of which is then compared to the no-IPV path $(0,0,0)$. Figure 4 provides a visual representation of the paths used in the decomposition exercise. By comparing skill deficits not only *vis-a-vis* the benchmark no-abuse path, but also *across* paths with varying durations of IPV exposure we can separate out the effect of *current* exposure from the effect of *prior* exposure.

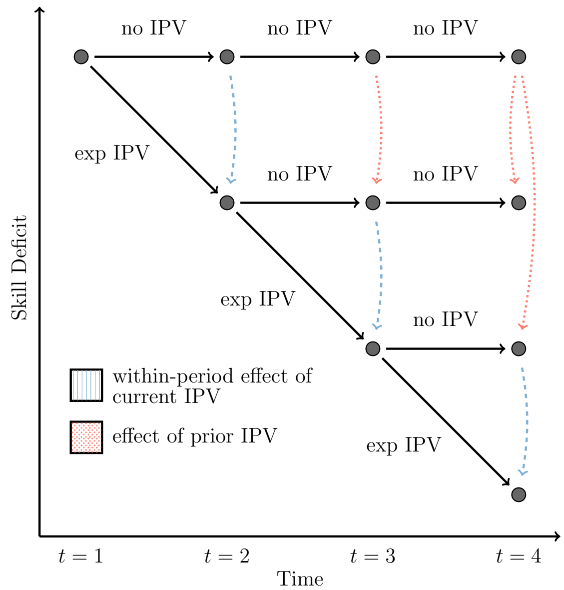
Table 4: Skill Deficits due to IPV Exposure

	Cognitive Skills (θ^c_{it})			Socio-Em. Skills (θ^e_{it})		
IPV exposure	$t=2$	$t=3$	$t=4$	$t=2$	$t=3$	$t=4$
(i) At $t=1$ only	-0.02	-0.02	-0.05	-0.14	-0.15	-0.14
(ii) At $t=1$ & 2	-	-0.07	-0.12	-	-0.27	-0.24
(iii) At all t	-	-	-0.11	-	-	-0.28

Notes: The table reports simulated skill deficits, based on the estimated model, comparing otherwise representative children with exposure to IPV in (i) the first period only ($\boldsymbol{q}_i = (1,0,0)$), (ii) the first two periods ($\boldsymbol{q}_i = (1,1,0)$), or (iii) all three development periods ($\boldsymbol{q}_i = (1,1,1)$), relative to corresponding children with no IPV exposure ($\boldsymbol{q}_i = (0,0,0)$). The simulated skill deficits are based on 200 replications where, in each replication, shocks to skills and inputs are drawn and are kept constant across the simulated paths.

Table 4 presents the simulated skill deficits. First, consider $t=2$ – when the child

Figure 4: Paths of IPV Exposure in the Decomposition Exercise



Notes: The figure illustrates the full IPV paths used in the decomposition exercise.

is 24 months old. Deficits at this time are attributable only to IPV exposure in the first development period. These current (or "within-period") effects are represented by the blue dashed line at $t = 2$ in Figure 4. The implied skill deficits at this stage are 0.02 and 0.14 units for cognitive and socio-emotional skills respectively, indicating that IPV during the first two years is particularly detrimental for socio-emotional skills.

Next, an additional period of IPV exposure leads to substantially larger deficits by time $t = 3$ – at just over three years of age — of 0.07 and 0.27 units for cognitive and socio-emotional skills respectively. However, it also highlights that if the same child had *not* been exposed to IPV in the second development period there would still be deficits of 0.02 and 0.15 units respectively. This is due to the prior effect of the IPV experienced in the first period, represented by the red dotted at $t = 3$ in Figure 4. For socio-emotional skills, the prior effect accounts for more than half of the deficit at $t = 3$, whilst for cognitive skills it accounts for about a third of the deficit after two consecutive periods of IPV exposure. The prior effects highlight how the effects of single period of early exposure remain even if the IPV subsequently stops. The differences between two periods of exposure versus only one such period for the two skills respectively – capture the current effects of IPV this period and is represented by the blue dashed line at $t = 3$ in Figure 4.

Finally, the third column in 4 shows that with three consecutive periods of IPV exposure the deficits continue to grow to 0.11 and 0.28 units respectively by time $t = 4$. It further shows that the deficits at $t = 4$ would have been 0.12 and 0.24 respectively had there been exposure only in the first two development periods. These are the effects of two periods of prior IPV exposure (represented by the long red dotted line at $t = 4$ in Figure 4). These prior effects strongly dominate the current effect of a third consecutive period of IPV exposure. Similarly, if the child had prior exposure only in the first period the deficits at $t = 4$ would have been 0.05 and 0.14 respectively (represented by the short red dotted line at $t = 4$). For both skills the prior effects, at $t = 4$, of *two* previous periods of IPV exposure is substantially larger than the prior effect of only *one* period of IPV exposure. This indicates that early prevention of a continuation of IPV delivers *future* skill benefits.

To summarize so far, the decomposition results in Table 4 illustrate three main takeaways. First, there are *immediate effects* of early IPV exposure on both skills, but particularly so for socio-emotional skills. Second, *minimizing the duration* of IPV exposure is imperative: a second consecutive period of exposure is strongly detrimental to the child's skill accumulation and consolidates the negative impact of early exposure on skills. Third, past IPV exposure has *lasting effects*.

5.2 Decomposing the Current Effects

The decomposition exercise above was silent regarding whether policy interventions to boost inputs can potentially mitigate the adverse effects of IPV exposure. We now return to the notion that IPV-induced skill deficits arise either *directly* from exposure or *indirectly* by affecting parental investments and mother's mental health as inputs. Specifically, extending our simulation exercise, we can decompose the current effect on each skills in each period for children exposed to three consecutive periods of IPV.

Table 5 reiterates first the implied current effects for each skill and period (panel a). For each skill rows (i) - (iii) in panel (b) break the current effects down into the direct effect (via the TFP) and the indirect effects via the two inputs. These breakdowns were obtained by setting to zero (or "shutting down") the terms relating to that mechanism in the production function for that period.

Table 5: Decomposing the Current Effects of IPV Exposure on Next Period Skills

	Cognitive Skills (θ^c_{it})			Socio-Em. Skills (θ^e_{it})		
	$t = 2$	$t = 3$	$t = 4$	$t = 2$	$t = 3$	$t = 4$
a) Current effect						
	-0.02	-0.05	0.01	-0.14	-0.11	-0.04
b) Channel contribution shares (%)						
(i) Direct effect via TFP	35.1	7.4	100	21.3	0.0	61.5
(ii) Indirect effect via θ^p_{it}	64.9	0.0	0.0	4.0	0.0	0.0
(iii) Indirect effect via θ^h_{it}	0.0	92.6	0.0	74.7	100	38.5

Notes: In each period (on a path with $\boldsymbol{q}_i = (1, 1, 1)$) IPV will have a current effect on the next period skill $\theta^k_{i,t+1}$, for $k = c, e$. The current effect at t is the difference in the skill deficit at $t + 1$ when $q_{it} = 1$ compared to when $q_{it} = 0$, and corresponds to the difference between the leading diagonal and the first superdiagonal in Table 4. The current effect occurs through three possible channels: directly via the TFP ($\alpha^k_{q,t}$ in eq. 4) and indirectly via the inputs θ^p_{it} and θ^h_{it} (through $\delta^p_{q,t}$ in eq. 5 and $\delta^h_{q,t}$ in eq. 6). To calculate each channel's contribution, the above term can be "switched on or off" (i.e. left at its estimated value or set to zero) in the simulation. For each channel a Shapley value is calculated to measure its (average) marginal deficit contribution when switched on. The table reports each channel's marginal contribution as a share of the current effect.

Consider first cognitive skills. The current effect of IPV exposure in the first development period is relatively small, but reflects a combination of a direct effect and an indirect effect via parental investment. The within-period effect of a second period of IPV exposure is larger, but now obtain mainly indirectly via mother's mental health (that is, through the effect of $q_{i,2}$ on $\theta^h_{i,2}$ and the latter's marginal effect on $\theta^c_{i,3}$). As noted above, the decomposition finds no meaningful current effect of a third consecutive period of IPV exposure on cognitive cognitive skills, rendering the decomposition irrelevant.

In contrast, for socio-emotional skills the decomposition indicated negative current effects of each (additional) period of IPV exposure. Whilst the contributions of the mechanisms indicated by the decomposition are not entirely stable over time, they indicate that the impact via mother's mental health is substantial, particularly in the first two development periods when the within-period effects are particularly large.

This further decomposition thus indicates that, whilst IPV has current effects on each skill in each period (certainly up to age 3), the channels through which these occur appear to be quite different. For the socio-emotional skills the indirect effect of IPV via mother's mental health plays a central role particularly early on. For cognitive skills the same channel plays a role after age 2, but the early deficit (by age 2) obtains either via parental investments or directly. Taken together, this indicates that early interventions to mitigate the adverse effects of IPV may best involve a combination of support for mother's mental health and parental investments. We will consider this next.

6 Early Intervention Policy

In this section we explore the implications for policy. The dynamic complementarities in the skill production imply that early interventions are particularly beneficial as their benefits will reverberate forwards and also make subsequent inputs more productive (Cunha et al., 2010; Attanasio et al., 2020). We will present counterfactual simulations involving interventions targeted specifically on the first development period – up to age two – for children exposed to IPV in that period.

The interventions that we will consider, although abstract, have natural real-world counterparts. For instance, the Thinking Healthy Program was developed and tested in rural Pakistan to address perinatal depression through CBT between the last pregnancy month through to ten months post-birth. Follow-ups at six and twelve months showed strong reductions in depression rates and increased parental interactions with the infant. Conducting an additional seven-year follow-up, Baranov et al. (2020) found that, not only had the positive impacts on mothers' mental health persisted, the intervention also led to sustained larger time- and money-intensive parental investments, highlighting complementarity.

Other interventions are less targeted. Closer to our setting, the Sure Start program was launched in the UK in the late 1990s, targeting families with pre-school children to promote parent-child interaction activities with play and learning sessions etc. and to promote maternal mental health via counselling services and mental health support groups.[25] Other UK policies include the National Health Service (NHS) Perinatal Mental Health Services which supports mothers up to a year after childbirth.

Our analysis will build on the decomposition analysis above. We will continue to focus

[25] Carneiro et al. (2025) detail the programme's history and present a comprehensive analysis of its effects on various dimensions of children's outcomes. After 2010, however spending on early years services dropped significantly and Sure Start as originally conceived with a strong emphasis on universal early years support was largely dismantled.

on representative children with median/mode baseline characteristics and median initial skills, and on IPV paths with one, two or three periods of exposure starting in the first development period. The difference relative to the decompositions in Table 4 above is that, here, when a child is first exposed (at $t = 1$), we allow for a simultaneous one-period targeted intervention. The key focus will be on policies that boost parental investments or mother's mental health.

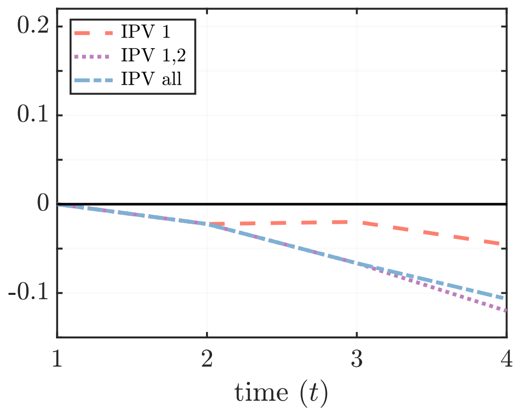
Specifically, we will consider interventions that deliver a *one standard deviation* increase in the relevant input – the parental investments ($\theta^p_{i,1}$) or mother's mental health ($\theta^h_{i,1}$). It should be noted from the outset that our counterfactual interventions are for illustrative purposes *intensionally implausibly large*. To see this note that, similar to the latent skills, ($\theta^p_{i,1}$) and ($\theta^h_{i,1}$) have approximately unit standard deviations (Table B.6). Moreover, Table 2 noted that the effect of IPV on mother's mental health in the first development period was approximately 0.6 units. Hence our counterfactual intervention that raises $\theta^h_{i,1}$ by one standard deviation *over-compensates* for the IPV effect. Similarly, Table 2 showed that IPV had a substantially smaller effect on the first period parental investments, so a one standard deviation increase in $\theta^p_{i,1}$ substantially over-compensates for the IPV effect on this input.

Our focus on over-compensating counterfactual early interventions serves to demonstrate the challenges of mitigating the adverse effects of IPV exposure when there are dynamic complementarities at play and also potential continued exposure. To put it differently, the natural "neutralizing" early intervention (ignoring direct effects of IPV) would involve a *combination* of maternal mental health support and parental investment support to exactly offset the adverse effects of IPV on these inputs along with the *elimination* of any further IPV exposure. In contrast, the below simulated policies intervene on one dimension at time – over-compensating in that single dimension – and may or may not be followed by further IPV exposure. The simulated effect of these counterfactual interventions are shown in Figures 5 and 6 for cognitive and socio-emotional skills respectively. As a benchmark, panel (a) in each figure is for the case of no-intervention and hence provides a graphical illustration of the deficits reported in Table 4.

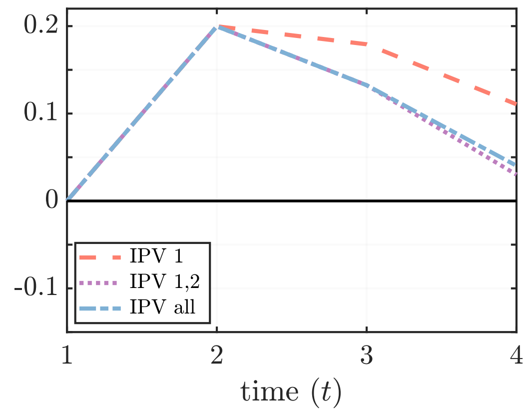
Consider first the cognitive skills (Figure 5). An early intervention increasing parental investments (by one s.d. – panel b) would substantially over-compensate for the negative

Figure 5: Cognitive Skill Deficits under Targeted Early Interventions

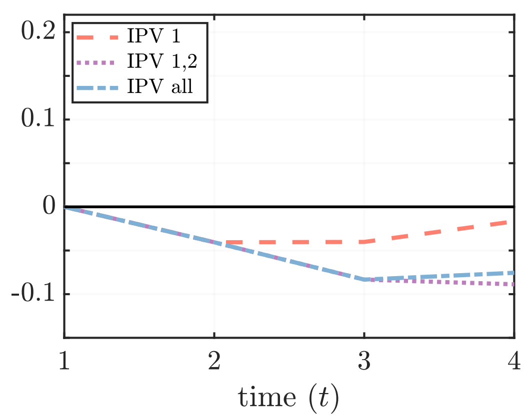
(a) No intervention



(b) Parental investment int.



(c) Mental health int.



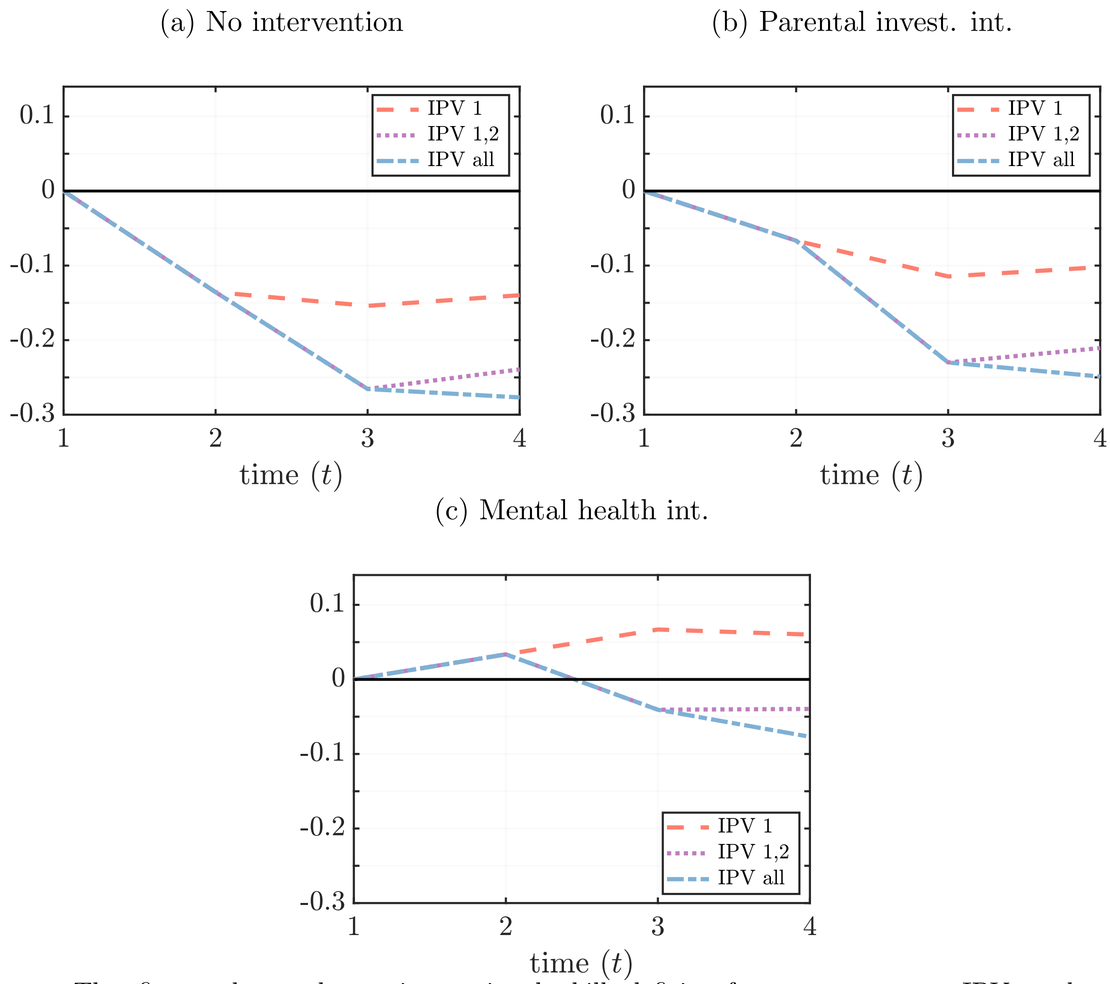
Notes: The figure shows the cognitive skill deficits from exposure to IPV paths $\boldsymbol{q}_i \in \{(1,0,0),(1,1,0),(1,1,1)\}$ relative to the no-IPV path $\boldsymbol{q}_i = (0,0,0)$. Panel (a) is for the case of no intervention and illustrates the deficits in Table 4. In panels (b) - (c) all children who experience first period IPV are targeted by a simultaneous first period intervention. In panel (b) the intervention is a one s.d. increase in parental investments ($\theta^p_{i,1}$). In panel (c) the intervention is a one s.d. increase in mother's mental health ($\theta^h_{i,1}$).

impact of IPV exposure in the short run (by time $t = 2$). This reflects the importance of parental investments for the cognitive skill development in the first development period (Table 3). However, the effect of the intervention is gradually eroded over the following years. This is not surprising since the intervention did not mitigate the IPV's effect on the mother's mental health. Further, unless subsequent IPV is prevented, the early advantage generated by the over-compensating intervention on parental investments is effectively lost by $t = 4$. An intervention to boost mother's mental health (by one s.d. – panel c) is less effective at offsetting the IPV-induced cognitive skill deficits. It would provide partial mitigation, but its effects mainly occur *after* the intervention, reducing the skill deficits at $t = 3$ and $t = 4$, through dynamic complementarities. For instance, the intervention benefits the child's early socio-emotional skills ($\theta^e_{i,2}$, see below), which improves the mother's next period mental health ($\theta^h_{i,2}$) and, through this, also the child's subsequent cognitive skills ($\theta^c_{i,3}$ etc.). However, if the IPV continues, the positive impact on the child's cognitive skills from intervening to support mother's mental health are largely lost.

The conclusions for socio-emotional skills (Figure 6) are similar to those for cognitive skills, but interchanging the interventions. An intervention to support mother's mental health (by one s.d. – panel c), by over-compensating for the impact of IV on this input, would also over-compensate for the impact on the socio-emotional skills at age 2 ($\theta^e_{i,2}$). If subsequent IPV is eliminated, the advantage remains overall positive, but if not, a deficit will again emerge, though naturally smaller than in the absence of the intervention. An intervention that boosts parental investments (by one s.d. – panel b) would have a substantially smaller mitigating effect on the IPV-induced socio-emotional skill deficits. Intuitively, given the strong link between mother's mental health and socio-emotional skills an intervention only on parental investments fails to target the key input dimension.

To stress again, the counterfactual interventions simulated above were for illustrative purposes chosen to be implausibly large, to the point of being over-compensating in one input dimension at a time. In doing so, the analysis made three observations salient. First, it reinforced the insight from the decomposition exercise that minimizing the duration of IPV exposure is imperative. Second, multi-component interventions that bundle support for both parental investments and mother's mental health would be best placed to simultaneously mitigate IPV-induced deficits across the two skill dimensions. Third, to successfully offset the effects of IPV exposure – especially if the elimination of IPV cannot be guaranteed – will likely require follow-up interventions throughout the pre-school years.

Figure 6: Socio-Emotional Skill Deficits under Targeted Early Interventions



Notes: The figure shows the socio-emotional skill deficits from exposure to IPV paths $\boldsymbol{q}_i \in \{(1,0,0),(1,1,0),(1,1,1)\}$ relative to the no-IPV path $\boldsymbol{q}_i = (0,0,0)$. For a description of the illustrated interventions, see notes to Figure 5.

7 Conclusion

This paper studies how exposure to intimate partner violence (IPV) shapes the accumulation of cognitive and socio-emotional skills of children of pre-school age. We use data from the Avon Longitudinal Study of Parents and Children (ALSPAC) – an internationally unique UK longitudinal cohort data resource containing annual indicators of the incidence of IPV and rich measures of children's cognitive and socio-emotional skills and the home environment – to estimate a dynamic latent factor model of the joint process of parental investment, mother's mental health and child skill development, allowing for complementarities between all inputs, and critically for adverse effects of IPV.

We allow for both a *direct* effect of IPV —through the witnessing of abuse— and *indirect* effects —via changes in parental investment and mother's mental health. Comparing across the two skills, we find that, for socio-emotional skills the adverse effects of IPV are larger and more immediate, and to a large proportion driven by the changes in mother's mental health. The adverse effects on cognitive skills are generally smaller and develop more gradually, and are driven by a mixture of direct and indirect effects, including via changes in parental investments. In terms of the size of effects, the IPV-induced skill deficits imply that persistently exposed children fall behind by approximately 2-7 percentiles in the aggregate distribution by the end of the pre-school years.

Our findings on the importance of parental investments and mother's mental health – both positively as inputs in the skill production function and as adversely affected by IPV – indicate that early intervention policies that combine support across these dimensions have the right components for mitigating the skill deficits induced by IPV. However, our analysis stressed that (i) such early interventions would need to be substantial, (ii) the dynamic effects of early IPV will continue to exert a negative effects even after IPV stops, and (iii) it is imperative that IPV is eliminated as quickly as possible for mitigating early intervention policies to make a longer run positive difference.

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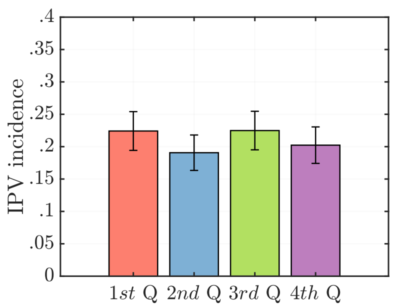
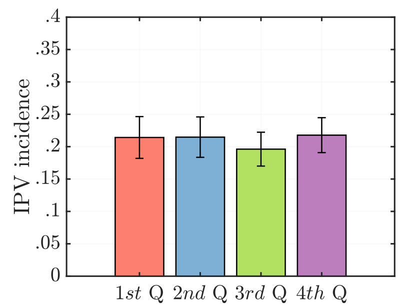
Appendices

A Additional Figures

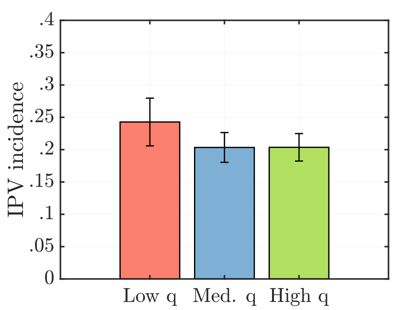
Figure A.1: IPV Incidence by Baseline Characteristics



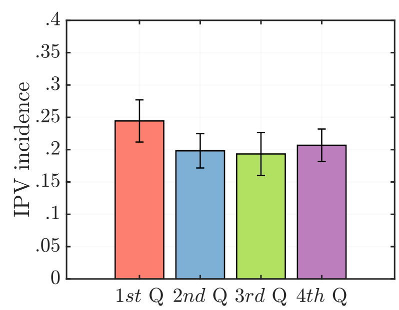
(a) Birth weight (quartiles)



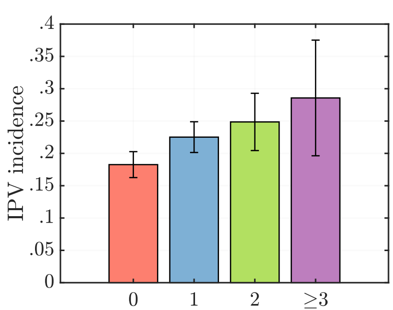
(b) Gestation period (quartiles)



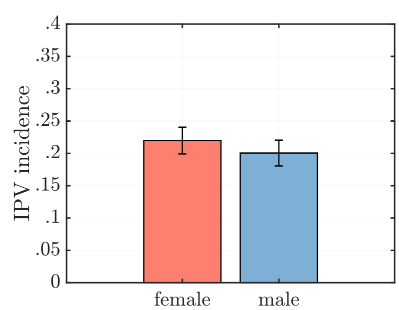
(c) Mother's qualifications



(d) Mother's age (quartiles)



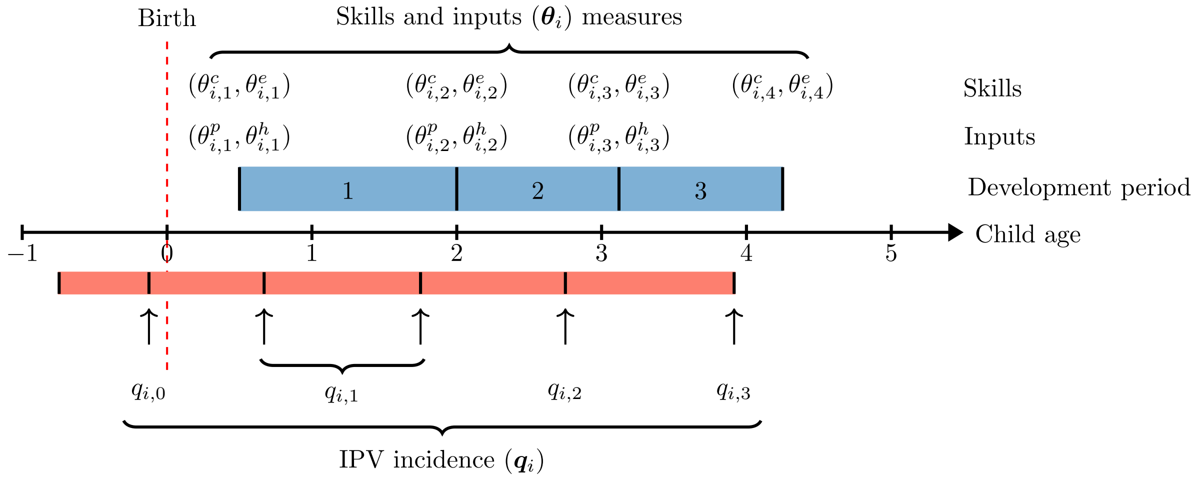
(e) Birth parity



(f) Child gender

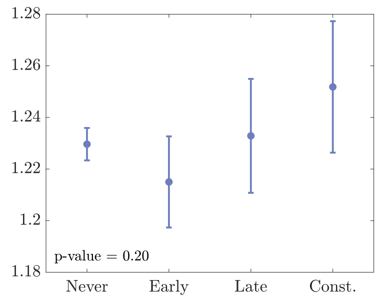
Notes: The figure shows how IPV incidence varies with baseline characteristics. See Table 1 for details on sample and characteristics. IPV incidence is measured as any report of either physical or emotional abuse by the mother at any of the five reporting occasions: when 32 weeks pregnant, and when the child was 8, 21, 33, and 47 months old respectively (see Section 2 for details).

Figure A.2: Stylized Timeline of the ALSPAC Data

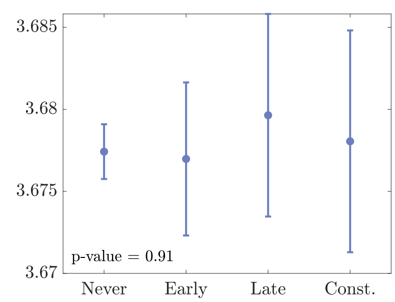


Notes: The figure shows a stylized timeline of measurements of child skills, θ^c_{it} and θ^e_{it}, of parental investments θ^p_{it} and mother's mental health θ^h_{it}, and of IPV incidence q_{it}.

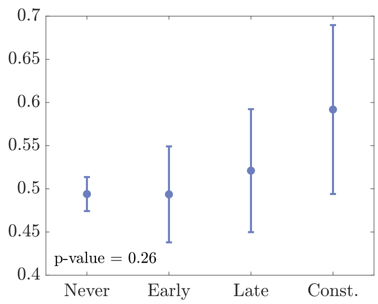
Figure A.3: Balance of Baseline Characteristics across Categories of IPV Paths



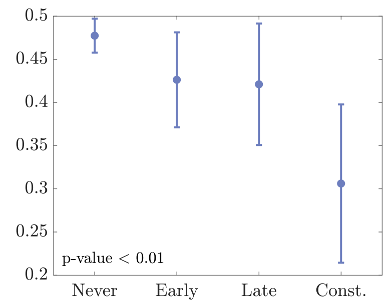
(a) Birth weight (log)



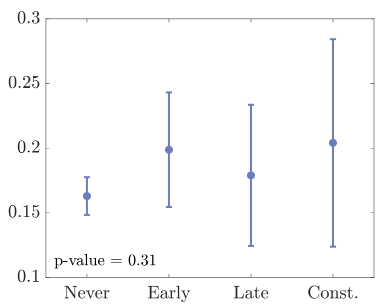
(b) Gestation period (log)



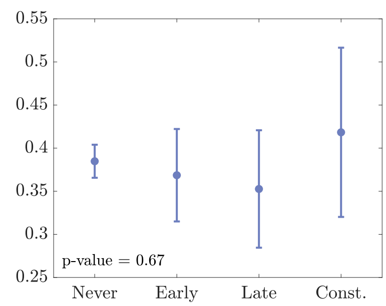
(c) Gender (female)



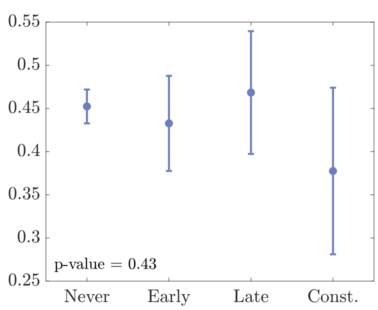
(d) First-born (parity zero)



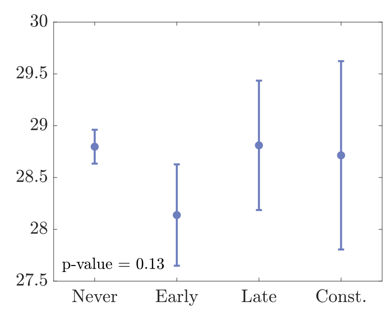
(e) Mother low qual.



(f) Mother medium qual.



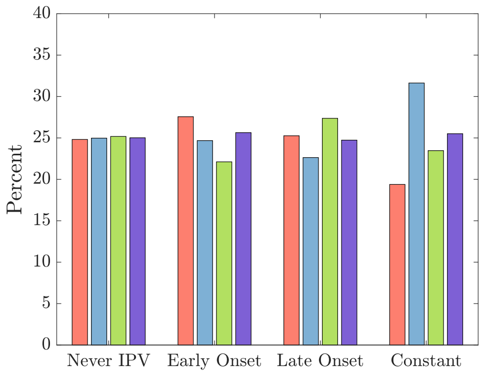
(g) Mother high qual.



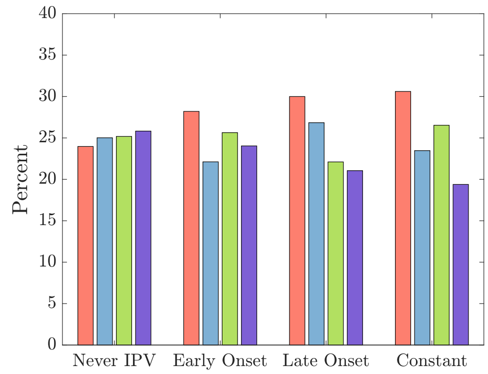
(h) Mother's age

Notes: The figure shows the means (with 95% confidence intervals) of child and mother baseline characteristics by category of IPV path. Children in the (i) "never IPV" category have the IPV path $\boldsymbol{q}_i = (0, 0, 0)$, (ii) "early onset" category have $q_{i,1} = 1$ but $\boldsymbol{q}_i \neq (1, 1, 1)$ (not "constant"), (iii) "late onset" category have $q_{i,1} = 0$ but $\boldsymbol{q}_i \neq (0, 0, 0)$ (not "never"), (iv) "constant IPV" category have the IPV path $\boldsymbol{q}_i = (1, 1, 1)$. The reported p-values are for ANOVA tests (alt. chi-square tests for binary variables) of no means (alt. proportion) differences across the four groups.

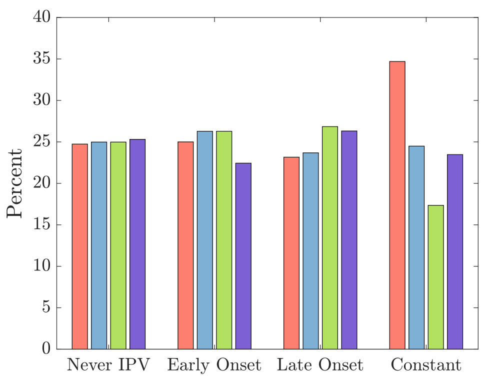
Figure A.4: Quartile Distributions of Initial and Terminal Skills by IPV Path Category



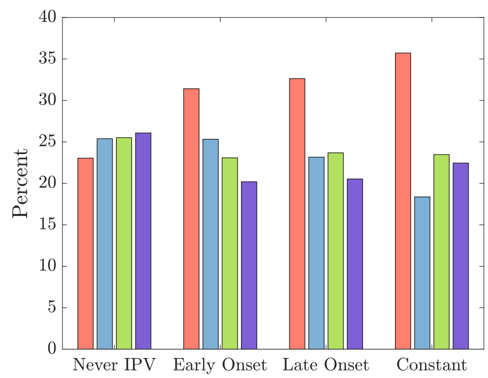
(a) Initial Cognitive Skills



(b) Terminal Cognitive Skills



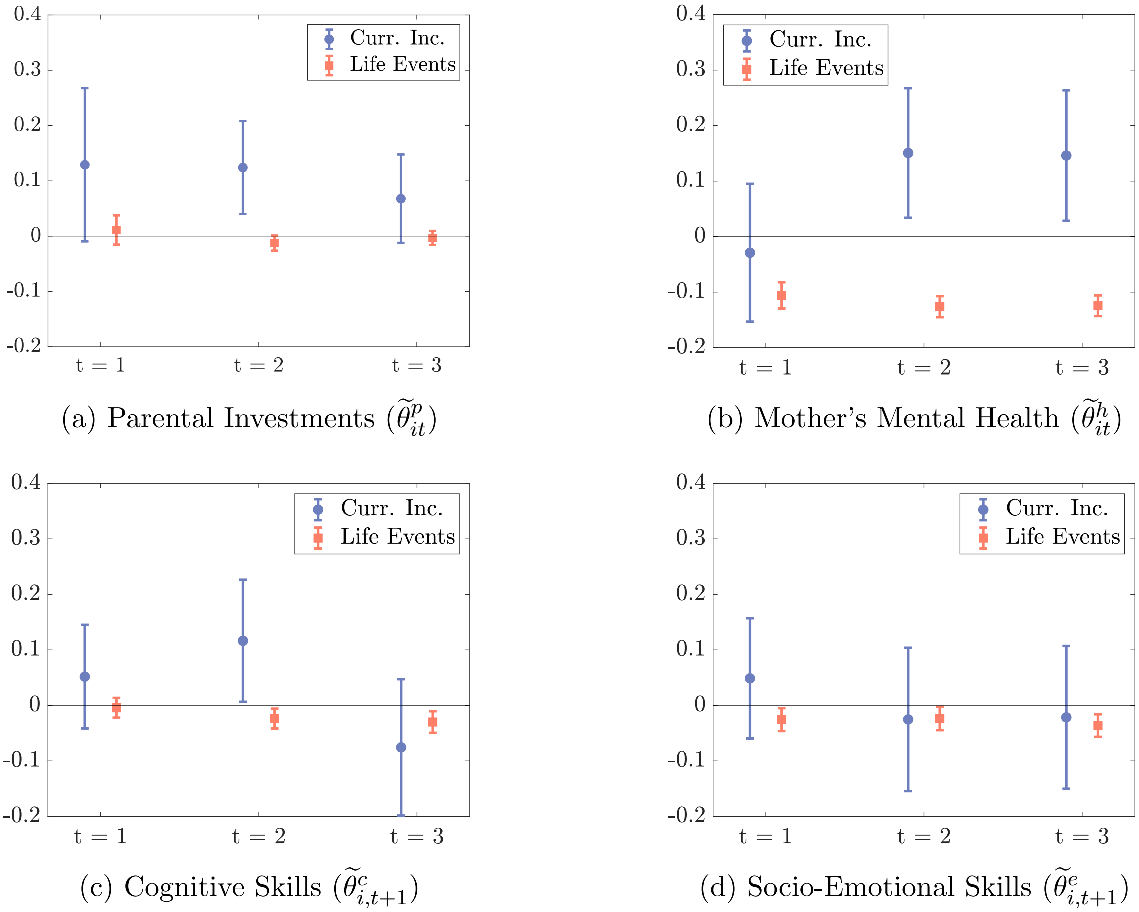
(c) Initial Socio-Emotional Skills



(d) Terminal Socio-Emotional Skills

Notes: The figure shows the percent of children who rank in the bottom, lower-middle, upper-middle and top quartile ($< 25th$, $25th - 50th$, $50th - 75th$ and $> 75th$ percentile) respectively by IPV path category for initial ($t = 1$) and terminal ($t = 4$) cognitive and socio-emotional skills. Children in the (i) "never IPV" category have the IPV path $\boldsymbol{q}_i = (0, 0, 0)$, (ii) "early onset" category have $q_{i,1} = 1$ but $\boldsymbol{q}_i \neq (1, 1, 1)$ (not "constant"), (iii) "late onset" category have $q_{i,1} = 0$ but $\boldsymbol{q}_i \neq (0, 0, 0)$ (not "never"), (iv) "constant IPV" category have the IPV path $\boldsymbol{q}_i = (1, 1, 1)$.

Figure A.5: Relating the Bartlett Factor Scores for the Latent Variables to the Instruments



(a) Parental Investments ($\widetilde{\theta}^{p}_{it}$)

(b) Mother's Mental Health ($\widetilde{\theta}^{h}_{it}$)

(c) Cognitive Skills ($\widetilde{\theta}^{c}_{i,t+1}$)

(d) Socio-Emotional Skills ($\widetilde{\theta}^{e}_{i,t+1}$)

Notes: The figures plots estimated coefficients, $\delta^k_{y,t}$ and $\delta^k_{l,t}$, on the instruments – current income ($w^y_{i,t}$) and life events index ($w^l_{i,t}$) – from regressions of the Bartlett factor scores. For the inputs (parental investment, $k = p$, and mother's mental health, $k = p$) the regressions take the form $\widetilde{\theta}^k_{it} = \delta^k_t + \delta^k_{y,t} w^y_{it} + \delta^k_{l,t} w^l_{it} + \boldsymbol{x}_i' \boldsymbol{\delta}^k_{x,t} + \delta^k_{q,t} q_{it} + \eta^k_{it}$ and thus additionally control for baseline characteristics and IPV incidence. For the skills (cognitive, $k = c$, and socio-emotional, $k = e$) the regressions take the form, $\widetilde{\theta}^k_{i,t+1} = \delta^k_t + \delta^k_{k,t} \widetilde{\theta}^k_{i,1} + \delta^k_{y,t} w^y_{it} + \phi^k_{l,t} w^l_{it} + \boldsymbol{x}_i' \boldsymbol{\delta}^k_{x,t} + \delta^k_{q,t} q_{it} + \eta^k_{it}$ and thus additionally control for baseline characteristics, initial skill (factor score) and IPV incidence. 95% confidence intervals are shown with error bars.

B Additional Tables

Table B.1: Measurement System: Cognitive Skills

Measure of cognitive skill (Z^c_{itm})	Time (t)	Intercept (μ^c_{tm})	Factor loading (λ^c_{tm})	Signal to noise ratio	Error var. (σ^2_{ctm})
Social skills, Denver subscore	1	0	1	0.376	0.626
		-	-	(0.031)	(0.026)
Fine motor skills, Denver subscore	1	0.023	1.175	0.520	0.482
		(0.024)	(0.069)	(0.029)	(0.029)
Gross motor skills, Denver subscore	1	0.020	1.036	0.404	0.598
		(0.021)	(0.067)	(0.025)	(0.032)
Social skills, Denver subscore	2	0	1	0.394	0.598
		-	-	(0.050)	(0.046)
Fine motor skills, Denver subscore	2	-0.032	0.963	0.360	0.640
		(0.022)	(0.053)	(0.041)	(0.051)
Gross motor skills, Denver subscore	2	-0.035	1.050	0.428	0.571
		(0.024)	(0.173)	(0.070)	(0.070)
Comm. skills, Denver subscore	2	-0.030	0.896	0.312	0.688
		(0.022)	(0.164)	(0.064)	(0.065)
Social skills, Denver subscore	3	0	1	0.577	0.451
		-	-	(0.028)	(0.023)
Fine motor skills, Denver subscore	3	0.015	0.927	0.532	0.465
		(0.020)	(0.041)	(0.024)	(0.026)
Gross motor skills, Denver subscore	3	0.011	0.686	0.290	0.707
		(0.020)	(0.043)	(0.025)	(0.030)
Word combination score	3	0.009	0.535	0.177	0.822
		(0.019)	(0.045)	(0.023)	(0.056)
Plurals score	3	0.009	0.552	0.188	0.810
		(0.019)	(0.048)	(0.023)	(0.032)
Social skills, Denver subscore	4	0	1	0.612	0.383
		-	-	(0.034)	(0.032)
Fine motor skills, Denver subscore	4	0.004	0.781	0.368	0.631
		(0.018)	(0.039)	(0.026)	(0.027)
Gross motor skills, Denver subscore	4	0.002	0.496	0.149	0.851
		(0.017)	(0.042)	(0.022)	(0.027)

Notes: The table presents estimated parameters of the measurement system (1) for cognitive skills θ^c_{it}, measured at time $t = 1, 2, 3, 4$. Standard errors in parenthesis.

Table B.2: Measurement System: Socio-Emotional Skills

Measure of socio-emotional skill (Z^e_{itm})	Time (t)	Intercept (μ^e_{tm})	Factor loading (λ^e_{tm})	Signal to noise ratio	Error var. (σ^2_{etm})
CIT mood score	1	0	1	0.494	0.507
		-	-	(0.023)	(0.021)
CIT rhythmicity score	1	0.015	0.596	0.175	0.825
		(0.018)	(0.030)	(0.016)	(0.028)
CIT approach score	1	0.027	1.098	0.594	0.407
		(0.020)	(0.046)	(0.020)	(0.019)
CIT adaptability score	1	0.028	1.134	0.634	0.367
		(0.020)	(0.047)	(0.021)	(0.020)
CIT intensity score	1	0.005	0.189	0.018	0.982
		(0.020)	(0.035)	(0.006)	(0.028)
CIT activity score	1	0.002	0.067	0.002	0.997
		(0.019)	(0.031)	(0.002)	(0.023)
CIT persistence score	1	0.015	0.614	0.186	0.814
		(0.017)	(0.027)	(0.016)	(0.022)
CIT distractability score	1	0.023	0.922	0.419	0.582
		(0.017)	(0.030)	(0.019)	(0.018)
CIT mood score	2	0	1	0.553	0.440
		-	-	(0.032)	(0.025)
CIT rhythmicity score	2	0.002	0.412	0.092	0.907
		(0.017)	(0.030)	(0.012)	(0.023)
CIT approach score	2	0.002	0.354	0.068	0.931
		(0.018)	(0.031)	(0.014)	(0.023)
CIT adaptability score	2	0.005	1.082	0.639	0.360
		(0.019)	(0.056)	(0.025)	(0.025)
CIT intensity score	2	0.003	0.691	0.261	0.739
		(0.017)	(0.046)	(0.021)	(0.024)
CIT activity score	2	0.003	0.657	0.235	0.764
		(0.019)	(0.055)	(0.024)	(0.025)
CIT persistence score	2	0.003	0.563	0.173	0.827
		(0.018)	(0.039)	(0.019)	(0.023)
CIT distractability score	2	0.001	0.129	0.009	0.991
		(0.018)	(0.031)	(0.004)	(0.028)
EAS emotionality score	3	0	1	0.586	0.411
		-	-	(0.156)	(0.160)
EAS shyness score	3	0.000	0.342	0.068	0.932
		(0.023)	(0.307)	(0.078)	(0.081)
EAS activity score	3	0.000	0.463	0.125	0.875
		(0.025)	(0.392)	(0.125)	(0.123)
EAS emotionality score	4	0	1	0.578	0.431
		-	-	(0.156)	(0.166)
EAS shyness score	4	0.000	0.386	0.088	0.911
		(0.021)	(0.308)	(0.091)	(0.092)
EAS activity score	4	0.000	0.466	0.128	0.871
		(0.023)	(0.390)	(0.135)	(0.134)

Notes: The table presents estimated parameters of the measurement system (1) for socio-emotional skills θ^e_{it}, measured at time $t = 1, 2, 3, 4$. Standard errors in parenthesis.

Table B.3: Measurement System: Parental Investments

Measure of investment (Z^p_{itm})	Time (t)	Intercept (μ^p_{tm})	Factor loading (λ^p_{tm})	Signal to noise ratio	Error var. (σ^2_{ptm})
Activity score	1	0	1	0.277	1.012
		-	-	(0.043)	(0.059)
Home score	1	-0.308	0.621	0.149	0.851
		(0.041)	(0.063)	(0.022)	(0.027)
Parenting score	1	-0.407	0.821	0.261	0.739
		(0.053)	(0.102)	(0.029)	(0.032)
Activity score	2	0	1	0.310	0.716
		-	-	(0.055)	(0.049)
Home score	2	3.956	2.220	0.184	7.018
		(0.290)	(0.268)	(0.036)	(1.048)
Parenting score	2	-0.006	1.275	0.525	0.473
		(0.032)	(0.205)	(0.070)	(0.068)
Activity score	3	0	1	0.222	0.834
		-	-	(0.055)	(0.053)
Home score	3	0.594	0.523	0.073	0.827
		(0.020)	(0.122)	(0.019)	(0.034)
Parenting score	3	0.037	1.591	0.604	0.396
		(0.034)	(0.288)	(0.088)	(0.087)

Notes: The table presents estimated parameters of the measurement system (1) for parental investments θ^p_{it}, measured at time $t = 1, 2, 3$. Standard errors in parenthesis.

Table B.4: Measurement System: Mother's Mental Health

Measure of mental health (Z^h_{itm})	Time (t)	Intercept (μ^h_{tm})	Factor loading (λ^h_{tm})	Signal to noise ratio	Error var. (σ^2_{htm})
EPDS score	1	0	1	0.745	0.261
		-	-	(0.015)	(0.013)
Anxiety score	1	-0.023	1.006	0.778	0.221
		(0.015)	(0.025)	(0.015)	(0.014)
Somatic score	1	-0.016	0.708	0.384	0.614
		(0.018)	(0.031)	(0.019)	(0.022)
Depression score	1	-0.022	0.956	0.702	0.297
		(0.017)	(0.025)	(0.016)	(0.013)
EPDS score	2	0	1	0.748	0.250
		-	-	(0.013)	(0.010)
Anxiety score	2	0.021	1.029	0.785	0.215
		(0.014)	(0.021)	(0.013)	(0.011)
Somatic score	2	0.014	0.672	0.335	0.665
		(0.016)	(0.029)	(0.020)	(0.027)
Depression score	2	0.020	0.995	0.734	0.266
		(0.014)	(0.022)	(0.014)	(0.013)
EPDS score	3	0	1	0.728	0.279
		-	-	(0.015)	(0.014)
Anxiety score	3	-0.006	1.024	0.784	0.215
		(0.015)	(0.023)	(0.013)	(0.011)
Somatic score	3	-0.004	0.705	0.371	0.627
		(0.016)	(0.031)	(0.022)	(0.027)
Depression score	3	-0.005	0.994	0.739	0.259
		(0.015)	(0.024)	(0.013)	(0.012)

Notes: The table presents estimated parameters of the measurement system (1) for parental investments θ^h_{it}, measured at time $t = 1, 2, 3$. Standard errors in parenthesis.

Table B.5: Descriptives of the Bartlett Skill Factor Scores

a) Within skill correlations over time: corr$(\theta^k_{it}, \theta^k_{i,t'})$		$t=1$	$t=2$	$t=3$	$t=4$
	$t=1$	-	0.371	0.239	0.194
Socio-emotional skills:($k=e$): above diag.	$t=2$	0.368	-	0.332	0.280
Cognitive skills:($k=c$): below diag.	$t=3$	0.290	0.664	-	0.621
	$t=4$	0.234	0.507	0.629	-
b) Across skill correlation by period		$t=1$	$t=2$	$t=3$	$t=4$
Skill corr.: *corr*$(\theta^c_{it}, \theta^e_{it})$		0.019	0.193	0.079	0.238
b) Standard deviation by skill and period		$t=1$	$t=2$	$t=3$	$t=4$
Cognitive skills: *st.dev.*(θ^c_{it})		0.735	0.745	0.874	0.932
Socio-emotional skills: *st.dev*(θ^e_{it})		0.766	0.828	0.963	0.958

Notes: The table presents descriptive statistics on the Bartlett factor scores for the latent cognitive and socio-emotional skills, estimated at the individual level from the observable measures and the estimated measurement system eq. (1).

Table B.6: Descriptives of the Bartlett Input Factor Scores

a) Within input correlations over time: corr$(\theta^k_{it}, \theta^k_{i,t'})$		$t=1$	$t=2$	$t=3$
Mother's mental health ($k=h$): above diag.	$t=1$	-	0.667	0.629
Parental investments ($k=p$): below diag.	$t=2$	0.487	-	0.749
	$t=3$	0.432	0.647	-
b) Across input correlation by period		$t=1$	$t=2$	$t=3$
Skill corr.: *corr*$(\theta^p_{it}, \theta^h_{it})$		0.085	0.110	0.067
b) Standard deviation by input and period		$t=1$	$t=2$	$t=3$
Parental investments: *st.dev.*(θ^p_{it})		1.007	0.621	0.585
Mother's mental health: *st.dev*(θ^h_{it})		0.916	0.903	0.903

Notes: The table presents descriptive statistics on the Bartlett factor scores for the latent inputs – parental investments and mother's mental health – estimated at the individual level from the observable measures and the estimated measurement system eq. (1).

Table B.7: Parental Investments and Mother's Mental Health

	Parental investment (θ_t^p)			Mother's mental health (θ_t^h)		
	$t = 1$	$t = 2$	$t = 3$	$t = 1$	$t = 2$	$t = 3$
a) Intimate partner violence						
IPV exposure	-0.06	-0.00	0.01	-0.57	-0.65	-0.55
	[-0.13, 0.00]	[-0.05, 0.05]	[-0.04, 0.05]	[-0.65, -0.48]	[-0.75, -0.54]	[-0.66, -0.44]
b) Skills and inputs						
Cognitive skills	0.46	-0.14	-0.20	0.05	-0.09	-0.03
	[0.33, 0.58]	[-0.23, -0.05]	[-0.28, -0.13]	[-0.01, 0.11]	[-0.17, -0.01]	[-0.10, 0.05]
Socio-emotional skills	0.04	0.01	-0.03	0.24	0.23	0.20
	[-0.02, 0.10]	[-0.05, 0.06]	[-0.08, 0.02]	[0.20, 0.29]	[0.18, 0.28]	[0.15, 0.25]
Mother's mental health (lag)	-	0.84	0.71	-	-	-
		[0.69, 0.99]	[0.53, 0.89]			
Parental investment (lag)	-	-	-	-	0.22	0.18
					[0.11, 0.33]	[0.07, 0.29]
c) Baseline characteristics and instruments						
Birthweight (log)	0.07	0.04	0.00	0.11	0.11	0.15
	[-0.04, 0.18]	[-0.03, 0.11]	[-0.06, 0.06]	[-0.07, 0.29]	[-0.07, 0.28]	[-0.03, 0.33]
Gest. period (log)	-0.33	-0.10	-0.06	0.54	0.33	0.67
	[-0.75, 0.09]	[-0.37, 0.16]	[-0.28, 0.15]	[-0.19, 1.26]	[-0.28, 0.94]	[-0.04, 1.38]
Birth parity	-0.06	-0.00	-0.01	-0.05	-0.03	-0.03
	[-0.08, -0.03]	[-0.01, 0.01]	[-0.02, -0.00]	[-0.08, -0.01]	[-0.06, -0.00]	[-0.06, -0.00]
Female	-0.06	-0.01	0.01	-0.01	-0.01	-0.02
	[-0.10, -0.01]	[-0.05, 0.03]	[-0.02, 0.04]	[-0.06, 0.03]	[-0.06, 0.04]	[-0.07, 0.02]
Med. edu.	0.05	0.02	0.00	0.04	0.05	0.09
	[-0.00, 0.10]	[-0.01, 0.05]	[-0.02, 0.03]	[-0.03, 0.11]	[-0.02, 0.12]	[0.01, 0.16]
High edu.	0.15	0.04	0.02	0.06	0.02	0.03
	[0.08, 0.22]	[0.01, 0.08]	[-0.01, 0.05]	[-0.01, 0.13]	[-0.05, 0.09]	[-0.05, 0.10]
Partner	-0.12	-0.07	-0.10	-0.03	0.29	0.30
	[-0.24, -0.01]	[-0.13, -0.01]	[-0.15, -0.05]	[-0.21, 0.15]	[0.12, 0.46]	[0.14, 0.47]
Income (log)	0.11	0.02	0.01	0.01	0.13	0.15
	[0.07, 0.16]	[-0.00, 0.04]	[-0.02, 0.03]	[-0.06, 0.09]	[0.05, 0.20]	[0.09, 0.22]
Life events	0.00	-0.01	0.00	-0.09	-0.11	-0.11
	[-0.01, 0.01]	[-0.01, 0.00]	[-0.01, 0.01]	[-0.11, -0.08]	[-0.12, -0.10]	[-0.12, -0.09]
Cons.	1.44	-0.08	-0.07	-1.88	-1.81	-3.14
	[-0.04, 2.93]	[-1.04, 0.87]	[-0.85, 0.72]	[-4.45, 0.68]	[-3.97, 0.36]	[-5.68, -0.60]
Error var.	0.29	0.08	0.08	0.67	0.60	0.63
	[0.20, 0.38]	[0.05, 0.11]	[0.05, 0.11]	[0.61, 0.72]	[0.55, 0.65]	[0.58, 0.69]

Notes: The table presents parameter estimates for the reduced-form equations for parental investments (5) and mother's mental health (6) for each development period $t = 1, 2, 3$. 90% confidence intervals in square brackets are computed using 200 bootstrap replications.

Table B.8: Production Function Parameter Estimates - Cognitive Skills

	Baseline model			Endogenous inputs		
	$t=1$	$t=2$	$t=3$	$t=1$	$t=2$	$t=3$
a) Cognitive skills						
$\gamma^c_{c,t}$	0.36	1.06	0.78	0.36	1.05	0.78
	[0.25, 0.47]	[0.99, 1.12]	[0.71, 0.85]	[0.25, 0.47]	[0.96, 1.15]	[0.71, 0.85]
$\gamma^c_{cc,t}$	-0.08	-0.20	-0.02	-0.08	-0.20	-0.02
	[-0.14, -0.01]	[-0.24, -0.16]	[-0.07, 0.02]	[-0.14, -0.01]	[-0.26, -0.14]	[-0.07, 0.02]
b) Socio-emotional skills						
$\gamma^c_{e,t}$	0.02	-0.04	0.19	0.02	-0.04	0.19
	[-0.03, 0.08]	[-0.07, -0.01]	[0.12, 0.27]	[-0.03, 0.08]	[-0.09, 0.01]	[0.12, 0.27]
$\gamma^c_{ee,t}$	0.01	-0.00	-0.01	0.01	-0.00	-0.01
	[-0.02, 0.04]	[-0.02, 0.01]	[-0.04, 0.02]	[-0.02, 0.04]	[-0.02, 0.02]	[-0.05, 0.02]
c) Parental investment						
$\gamma^c_{p,t}$	0.34	-0.02	0.03	0.34	-0.01	0.04
	[0.22, 0.46]	[-0.08, 0.03]	[-0.05, 0.11]	[0.22, 0.46]	[-0.11, 0.08]	[-0.05, 0.12]
$\gamma^c_{pp,t}$	0.01	-0.01	0.00	0.01	-0.01	0.00
	[-0.05, 0.07]	[-0.05, 0.03]	[-0.05, 0.05]	[-0.05, 0.07]	[-0.06, 0.05]	[-0.05, 0.05]
d) Mother's mental health						
$\gamma^c_{h,t}$	-0.02	0.09	0.00	-0.02	0.08	0.00
	[-0.08, 0.05]	[0.07, 0.12]	[-0.05, 0.05]	[-0.08, 0.05]	[0.03, 0.14]	[-0.05, 0.06]
$\gamma^c_{hh,t}$	-0.00	0.03	0.01	-0.00	0.03	0.01
	[-0.03, 0.02]	[0.02, 0.04]	[-0.02, 0.04]	[-0.03, 0.02]	[0.00, 0.06]	[-0.02, 0.04]
e) Interactions						
$\gamma^c_{ce,t}$	-0.01	-0.02	-0.03	-0.01	-0.02	-0.03
	[-0.08, 0.06]	[-0.05, 0.01]	[-0.09, 0.04]	[-0.08, 0.06]	[-0.07, 0.03]	[-0.10, 0.04]
$\gamma^c_{cp,t}$	-0.02	0.09	0.07	-0.02	0.09	0.07
	[-0.13, 0.08]	[0.03, 0.15]	[-0.02, 0.16]	[-0.13, 0.09]	[0.00, 0.17]	[-0.03, 0.16]
$\gamma^c_{ch,t}$	-0.00	-0.02	0.03	-0.00	-0.02	0.03
	[-0.08, 0.07]	[-0.05, -0.02]	[-0.03, 0.08]	[-0.08, 0.07]	[-0.08, 0.04]	[-0.03, 0.08]
$\gamma^c_{ep,t}$	0.03	0.03	-0.01	0.03	0.03	-0.00
	[-0.04, 0.10]	[-0.00, 0.06]	[-0.06, 0.05]	[-0.04, 0.10]	[-0.01, 0.07]	[-0.06, 0.05]
$\gamma^c_{eh,t}$	-0.01	-0.05	-0.02	-0.01	-0.05	-0.02
	[-0.05, 0.03]	[-0.08, -0.03]	[-0.07, 0.03]	[-0.06, 0.03]	[-0.10, -0.01]	[-0.07, 0.03]
$\gamma^c_{ph,t}$	-0.01	0.00	0.03	-0.01	0.00	0.03
	[-0.11, 0.08]	[-0.04, 0.04]	[-0.04, 0.10]	[-0.11, 0.08]	[-0.07, 0.07]	[-0.04, 0.11]

Notes: The table presents parameter estimates ($\boldsymbol{\gamma}^k_t$ and $\boldsymbol{\Gamma}^k_t$) from eq. (3) for cognitive skill ($k=c$) for each development period ($t=1,2,3$). 90% confidence intervals in square brackets are computed using 200 bootstrap replications.

Table B.9: Production Function Parameter Estimates - Socio-Emotional Skills

	Baseline model			Endogenous inputs		
	$t=1$	$t=2$	$t=3$	$t=1$	$t=2$	$t=3$
a) Cognitive skills						
$\gamma^e_{c,t}$	0.14	-0.12	0.05	0.14	-0.12	0.04
	[0.06, 0.21]	[-0.18, -0.05]	[-0.01, 0.10]	[0.06, 0.22]	[-0.23, -0.01]	[-0.01, 0.10]
$\gamma^e_{cc,t}$	-0.04	-0.01	-0.00	-0.04	-0.01	-0.00
	[-0.09, 0.01]	[-0.05, 0.03]	[-0.03, 0.03]	[-0.10, 0.01]	[-0.08, 0.05]	[-0.04, 0.03]
b) Socio-emotional skills						
$\gamma^e_{e,t}$	0.40	0.43	0.88	0.40	0.43	0.88
	[0.34, 0.47]	[0.29, 0.57]	[0.77, 1.00]	[0.34, 0.47]	[0.24, 0.81]	[0.77, 1.00]
$\gamma^e_{ee,t}$	-0.02	0.02	-0.03	-0.02	0.02	-0.03
	[-0.05, 0.01]	[-0.01, 0.04]	[-0.05, -0.00]	[-0.05, 0.01]	[-0.01, 0.05]	[-0.05, -0.00]
c) Parental investment						
$\gamma^e_{p,t}$	0.06	0.12	-0.03	0.06	0.19	-0.01
	[-0.04, 0.16]	[0.06, 0.17]	[-0.11, 0.06]	[-0.04, 0.17]	[0.01, 0.37]	[-0.11, 0.09]
$\gamma^e_{pp,t}$	0.02	0.00	-0.01	0.02	0.00	-0.01
	[-0.04, 0.08]	[-0.04, 0.04]	[-0.05, 0.03]	[-0.05, 0.09]	[-0.06, 0.07]	[-0.06, 0.03]
d) Mother's mental health						
$\gamma^e_{h,t}$	0.22	0.25	0.04	0.22	0.25	0.04
	[0.15, 0.28]	[0.19, 0.32]	[-0.02, 0.10]	[0.14, 0.29]	[0.13, 0.37]	[-0.02, 0.11]
$\gamma^e_{hh,t}$	0.04	0.07	-0.01	0.04	0.07	-0.01
	[0.01, 0.07]	[0.05, 0.09]	[-0.04, 0.03]	[0.01, 0.07]	[0.03, 0.11]	[-0.04, 0.03]
e) Interactions						
$\gamma^e_{ce,t}$	0.03	0.02	0.01	0.03	0.02	0.01
	[-0.04, 0.09]	[-0.02, 0.06]	[-0.04, 0.06]	[-0.04, 0.09]	[-0.03, 0.08]	[-0.04, 0.06]
$\gamma^e_{cp,t}$	0.00	-0.05	0.06	0.00	-0.05	0.06
	[-0.08, 0.09]	[-0.11, 0.02]	[-0.02, 0.14]	[-0.09, 0.09]	[-0.17, 0.07]	[-0.02, 0.15]
$\gamma^e_{ch,t}$	0.04	-0.04	-0.00	0.04	-0.04	-0.00
	[-0.04, 0.11]	[-0.09, 0.01]	[-0.05, 0.05]	[-0.04, 0.11]	[-0.12, 0.03]	[-0.05, 0.05]
$\gamma^e_{ep,t}$	0.04	-0.02	0.03	0.04	-0.02	0.03
	[-0.03, 0.10]	[-0.06, 0.02]	[-0.02, 0.08]	[-0.03, 0.11]	[-0.08, 0.04]	[-0.02, 0.08]
$\gamma^e_{eh,t}$	0.01	-0.03	0.01	0.01	-0.03	0.01
	[-0.03, 0.06]	[-0.07, 0.01]	[-0.05, 0.06]	[-0.03, 0.06]	[-0.09, 0.02]	[-0.05, 0.07]
$\gamma^e_{ph,t}$	-0.05	-0.01	0.03	-0.05	-0.01	0.03
	[-0.15, 0.04]	[-0.07, 0.04]	[-0.05, 0.11]	[-0.15, 0.05]	[-0.10, 0.08]	[-0.05, 0.11]

Notes: The table presents parameter estimates ($\boldsymbol{\gamma}^k_t$ and $\boldsymbol{\Gamma}^k_t$) from eq. (3) for socio-emotional skill ($k = e$) for each development period ($t = 1, 2, 3$). 90% confidence intervals in square brackets are computed using 200 bootstrap replications.

Table B.10: Total Factor Productivity - Cognitive Skills

	Initial skills	Baseline model			Endogenous inputs		
	$t=0$	$t=1$	$t=2$	$t=3$	$t=1$	$t=2$	$t=3$
a) Intimate Partner Violence							
IPV exposure	-	-0.01	0.00	0.00	-0.01	-0.00	-0.00
	-	[-0.06, 0.03]	[-0.03, 0.04]	[-0.04, 0.04]	[-0.06, 0.03]	[-0.03, 0.03]	[-0.04, 0.04]
b) Baseline Characteristics							
Birthweight	0.47	0.00	0.01	0.02	0.00	0.01	0.02
	[0.36, 0.59]	[-0.09, 0.09]	[-0.07, 0.09]	[-0.05, 0.09]	[-0.09, 0.09]	[-0.07, 0.09]	[-0.05, 0.09]
Gest. period	-0.07	0.02	0.00	-0.01	0.02	-0.00	-0.01
	[-0.11, -0.02]	[-0.02, 0.06]	[-0.03, 0.03]	[-0.03, 0.02]	[-0.02, 0.06]	[-0.03, 0.02]	[-0.04, 0.02]
Female	-0.10	-0.30	-0.06	0.01	-0.30	-0.06	0.01
	[-0.14, -0.07]	[-0.36, -0.23]	[-0.09, -0.03]	[-0.01, 0.04]	[-0.36, -0.23]	[-0.10, -0.02]	[-0.01, 0.04]
Parity	-0.09	0.01	0.01	0.02	0.01	0.01	0.02
	[-0.11, -0.06]	[-0.01, 0.03]	[-0.01, 0.02]	[0.01, 0.03]	[-0.01, 0.03]	[-0.01, 0.02]	[0.01, 0.03]
Medium ac. qual.	-0.02	0.01	0.01	0.03	0.01	0.01	0.03
	[-0.07, 0.03]	[-0.04, 0.05]	[-0.02, 0.04]	[0.01, 0.06]	[-0.04, 0.05]	[-0.02, 0.03]	[0.00, 0.06]
High ac. qual.	0.05	0.01	-0.02	-0.01	0.01	-0.02	-0.01
	[0.00, 0.10]	[-0.04, 0.05]	[-0.05, 0.01]	[-0.04, 0.03]	[-0.04, 0.05]	[-0.05, 0.01]	[-0.04, 0.03]
Partner	-0.14	-0.01	-0.01	-0.04	-0.01	-0.00	-0.04
	[-0.25, -0.03]	[-0.10, 0.08]	[-0.07, 0.05]	[-0.09, 0.01]	[-0.10, 0.08]	[-0.06, 0.05]	[-0.09, 0.01]
g) Test of exogeneity & prod. shocks							
θ_t^p residual	-	-	-	-	0.00	0.04	0.02
	-	-	-	-	[-0.00, 0.00]	[-0.09, 0.17]	[-0.11, 0.15]
θ_t^h residual	-	-	-	-	-0.00	-0.01	-0.00
	-	-	-	-	[-0.00, 0.00]	[-0.02, -0.00]	[-0.01, 0.01]
Std. dev. of shock$_t$	0.36	0.22	0.13	0.17	0.22	0.13	0.17
	[0.31, 0.42]	[0.16, 0.27]	[0.09, 0.18]	[0.13, 0.21]	[0.16, 0.27]	[0.08, 0.18]	[0.13, 0.21]

Notes: Notes: The table presents parameter estimates for the total factor productivity eqs. (4) for cognitive skills for the initial skills ($t = 0$) and each subsequent development period ($t = 1, 2, 3$). 90% confidence intervals in square brackets are computed using 200 bootstrap replications.

Table B.11: Total Factor Productivity - Socio-Emotional Skills

	Initial skills	Baseline model			Endogenous inputs		
	$t = 0$	$t = 1$	$t = 2$	$t = 3$	$t = 1$	$t = 2$	$t = 3$
a) Intimate Partner Violence							
IPV exposure	-	-0.03	0.02	-0.03	-0.03	0.02	-0.03
	-	[-0.08, 0.03]	[-0.04, 0.09]	[-0.06, 0.01]	[-0.08, 0.03]	[-0.04, 0.08]	[-0.06, 0.01]
b) Baseline Characteristics							
Birthweight	0.07	0.00	-0.06	-0.07	0.00	-0.07	-0.07
	[-0.07, 0.21]	[-0.12, 0.12]	[-0.20, 0.08]	[-0.13, -0.00]	[-0.12, 0.12]	[-0.21, 0.07]	[-0.13, -0.00]
Gest. period	-0.02	-0.03	0.02	0.03	-0.03	0.02	0.02
	[-0.09, 0.04]	[-0.07, 0.02]	[-0.04, 0.07]	[-0.00, 0.05]	[-0.08, 0.02]	[-0.04, 0.07]	[-0.00, 0.05]
Female	0.05	-0.05	0.14	0.03	-0.05	0.14	0.03
	[0.02, 0.09]	[-0.09, -0.01]	[0.08, 0.20]	[0.00, 0.06]	[-0.09, -0.01]	[0.09, 0.20]	[0.00, 0.06]
Parity	-0.04	0.01	0.01	0.01	0.01	0.02	0.01
	[-0.07, -0.02]	[-0.01, 0.04]	[-0.01, 0.04]	[-0.01, 0.02]	[-0.01, 0.04]	[-0.01, 0.05]	[-0.01, 0.02]
Medium ac. qual.	-0.01	0.09	-0.07	-0.01	0.09	-0.07	-0.01
	[-0.07, 0.05]	[0.04, 0.14]	[-0.13, -0.01]	[-0.04, 0.02]	[0.04, 0.14]	[-0.13, -0.02]	[-0.04, 0.02]
High ac. qual.	-0.01	0.12	-0.11	-0.04	0.12	-0.12	-0.04
	[-0.07, 0.05]	[0.07, 0.18]	[-0.17, -0.05]	[-0.07, -0.01]	[0.07, 0.18]	[-0.20, -0.05]	[-0.07, -0.01]
Partner	0.07	-0.03	-0.03	-0.00	-0.03	-0.02	0.00
	[-0.08, 0.22]	[-0.14, 0.08]	[-0.12, 0.06]	[-0.05, 0.05]	[-0.14, 0.08]	[-0.11, 0.08]	[-0.05, 0.05]
g) Test of exogeneity & prod. shocks							
θ_t^p residual	-	-	-	-	-0.00	0.09	0.05
	-	-	-	-	[-0.00, 0.00]	[-0.07, 0.25]	[-0.05, 0.15]
θ_t^h residual	-	-	-	-	-0.00	-0.01	0.00
	-	-	-	-	[-0.00, 0.00]	[-0.01, 0.00]	[-0.01, 0.01]
Std. dev. of shock$_t$	0.49	0.40	0.42	0.11	0.40	0.42	0.11
	[0.44, 0.54]	[0.35, 0.45]	[0.24, 0.59]	[0.00, 0.21]	[0.35, 0.45]	[0.25, 0.59]	[0.00, 0.21]

Notes: Notes: The table presents parameter estimates for the total factor productivity eqs. (4) for socio-emotional skills for the initial skills ($t = 0$) and each subsequent development period ($t = 1, 2, 3$). 90% confidence intervals in square brackets are computed using 200 bootstrap replications.

C Further Details of the Skill Model

Here we outline the derivation – which follows Aucejo and James (2021) – of the second-step likelihood function that is maximized to obtain estimates of the skill production function eqs. (3) and (4) and the reduced-form input eqs. (5) and (6). We also present the marginal effects ("elasticities") equations used for Table 3.

The Likelihood

Define $L(\boldsymbol{z}_i; \boldsymbol{x}_i, \boldsymbol{q}_i)$ as the probability of observing the measures data $\boldsymbol{z}_i$ for individual i given their exogenous data $(\boldsymbol{x}_i, \boldsymbol{q}_i)$. The conditional probability of observing $\boldsymbol{z}_i$ depends on the individual's latent factors $\boldsymbol{\theta}_i$ (via the measurement system) and which we denote $q(\boldsymbol{z}_i|\boldsymbol{\theta}_i)$. Moreover, the probability of $\boldsymbol{\theta}_i$ depends, as noted in eq. (7), on the observables via the production function (3) and the input functions, (5) and (6), and we write this as conditional probability $F(\boldsymbol{\theta}_i|\boldsymbol{x}_i, \boldsymbol{q}_i)$. Noting that $\boldsymbol{\theta}_i$ is unobserved, we then have that

$$L(\boldsymbol{z}_i; \boldsymbol{x}_i, \boldsymbol{q}_i) = \int_{\boldsymbol{\theta}_i} q(\boldsymbol{z}_i|\boldsymbol{\theta}_i) F(\boldsymbol{\theta}_i|\boldsymbol{x}_i, \boldsymbol{q}_i) \, d\boldsymbol{\theta}_i. \tag{C.1}$$

The log likelihood function is then $\ln \mathcal{L}(\Psi) = \sum_i \ln L(\boldsymbol{z}_i; \boldsymbol{x}_i, \boldsymbol{q}_i)$, and differentiating with respect to the parameters we obtain the score function

$$\frac{\partial \ln \mathcal{L}(\Psi)}{\partial \Psi} = \sum_i \frac{1}{L(\boldsymbol{z}_i; \boldsymbol{x}_i, \boldsymbol{q}_i)} \frac{\partial L(\boldsymbol{z}_i; \boldsymbol{x}_i, \boldsymbol{q}_i)}{\partial \Psi}. \tag{C.2}$$

Substitute for $L(\boldsymbol{z}_i; \boldsymbol{x}_i, \boldsymbol{q}_i)$ using (C.1), the score function can be rewritten as

$$\frac{\partial \ln \mathcal{L}(\Psi)}{\partial \Psi} = \sum_i \int_{\boldsymbol{\theta}_i} \frac{\partial \ln [q(\boldsymbol{z}_i|\boldsymbol{\theta}_i) F(\boldsymbol{\theta}_i|\boldsymbol{x}_i, \boldsymbol{q}_i)]}{\partial \Psi} \frac{q(\boldsymbol{z}_i|\boldsymbol{\theta}_i) F(\boldsymbol{\theta}_i|\boldsymbol{x}_i, \boldsymbol{q}_i)}{L(\boldsymbol{z}_i; \boldsymbol{x}_i, \boldsymbol{q}_i)} d\boldsymbol{\theta}_i. \tag{C.3}$$

Now, consider

$$\frac{q(\boldsymbol{z}_i|\boldsymbol{\theta}_i) F(\boldsymbol{\theta}_i|\boldsymbol{x}_i, \boldsymbol{q}_i)}{L(\boldsymbol{z}_i; \boldsymbol{x}_i, \boldsymbol{q}_i)} = \frac{\Pr(\boldsymbol{z}_i, \boldsymbol{\theta}_i|\boldsymbol{x}_i, \boldsymbol{q}_i)}{\Pr(\boldsymbol{z}_i|\boldsymbol{x}_i, \boldsymbol{q}_i)} = q(\boldsymbol{\theta}_i|\boldsymbol{x}_i, \boldsymbol{q}_i, \boldsymbol{z}_i) \tag{C.4}$$

where $q(\boldsymbol{\theta}_i|\boldsymbol{x}_i, \boldsymbol{q}_i, \boldsymbol{z}_i)$ is the probability of $\boldsymbol{\theta}_i$ conditional on all the individual's observable data $(\boldsymbol{x}_i, \boldsymbol{q}_i, \boldsymbol{z}_i)$. However, by the model assumptions, $\boldsymbol{\theta}_i$ is independent of $(\boldsymbol{x}_i, \boldsymbol{q}_i)$ once we condition on the individual's measures $\boldsymbol{z}_i$ whereby $q(\boldsymbol{\theta}_i|\boldsymbol{x}_i, \boldsymbol{q}_i, \boldsymbol{z}_i) = q(\boldsymbol{\theta}_i|\boldsymbol{z}_i)$ where the latter conditional probability entirely reflects the measurement system. Hence, substituting using (C.4), and splitting log product the score function can be written as

$$\frac{\partial \ln \mathcal{L}(\Psi)}{\partial \Psi} = \sum_i \int_{\boldsymbol{\theta}_i} \frac{\partial \ln q(\boldsymbol{z}_i|\boldsymbol{\theta}_i)}{\partial \Psi} q(\boldsymbol{\theta}_i|\boldsymbol{z}_i)\, d\boldsymbol{\theta}_i + \sum_i \int_{\boldsymbol{\theta}_i} \frac{\partial \ln F(\boldsymbol{\theta}_i|\boldsymbol{x}_i, \boldsymbol{q}_i)}{\partial \Psi} q(\boldsymbol{\theta}_i|\boldsymbol{z}_i)\, d\boldsymbol{\theta}_i. \quad \text{(C.5)}$$

The parameters of the production function eq. (3) and input eqs. (5) and (6) only enters the second component. Hence, these parameters can be estimated by maximizing (8) which has the above (second stage) score function.

Derivation of Marginal Effects

In this appendix we derive expressions for the marginal effects of current skills and current inputs on next period skills. Recall that all skill and input variables are defined to be in logs, so the marginal effects can be interpreted as elasticities. The marginal effects account for the current inputs, θ_{it}^p and θ_{it}^h, also being affected by the current skills, θ_{it}^c and θ_{it}^e, etc. as specified in (5) and (6).

Consider the production the next period skill $\theta_{i,t+1}^k$, for $k = c, e$. Differentiating (3) with respect to the current cognitive skill θ_{it}^c, and, using that from (5) and (6), $\partial\theta_{it}^p/\partial\theta_{it}^c = \delta_{c,t}^p$ and $\partial\theta_{it}^h/\partial\theta_{it}^c = \delta_{c,t}^h$, it follows that the marginal effect (total derivative) of the current cognitive skill θ_{it}^c on the future skill $\theta_{i,t+1}^k$, is given by

$$\begin{aligned} \frac{d\theta_{i,t+1}^k}{d\theta_{it}^c} = \; & \gamma_{c,t}^k + \gamma_{p,t}^k\delta_{c,t}^p + \gamma_{h,t}^k\delta_{c,t}^h + 2\gamma_{cc,t}^k\theta_{it}^c + 2\gamma_{pp,t}^k\delta_{c,t}^p\theta_{it}^p + 2\gamma_{hh,t}^k\delta_{c,t}^h\theta_{it}^h \\ & + \gamma_{ce,t}^k\theta_{it}^e + \gamma_{cp,t}^k\left(\theta_{it}^p + \delta_{c,t}^p\theta_{it}^c\right) + \gamma_{ch,t}^k\left(\theta_{it}^h + \delta_{c,t}^h\theta_{it}^c\right) \\ & + \gamma_{ep,t}^k\delta_{c,t}^p\theta_{it}^e + \gamma_{eh,t}^k\delta_{c,t}^h\theta_{it}^e + \gamma_{ph,t}^k\left(\delta_{c,t}^h\theta_{it}^p + \delta_{c,t}^p\theta_{it}^h\right). \end{aligned} \quad \text{(C.6)}$$

A corresponding expression holds for the marginal effect of the current socio-emotional skill, θ_{it}^e, on the future skill $\theta_{i,t+1}^k$,

$$\begin{aligned} \frac{d\theta_{i,t+1}^k}{d\theta_{it}^e} &= \gamma_{e,t}^k + \gamma_{p,t}^k \delta_{e,t}^p + \gamma_{h,t}^k \delta_{e,t}^h + 2\gamma_{ee,t}^k \theta_{it}^e + 2\gamma_{pp,t}^k \delta_{e,t}^p \theta_{it}^p + 2\gamma_{hh,t}^k \delta_{e,t}^h \theta_{it}^h \\ &\quad + \gamma_{ce,t}^k \theta_{it}^c + \gamma_{ep,t}^k \left(\theta_{it}^p + \delta_{e,t}^p \theta_{it}^e \right) + \gamma_{eh,t}^k \left(\theta_{it}^h + \delta_{e,t}^h \theta_{it}^e \right) \\ &\quad + \gamma_{cp,t}^k \delta_{e,t}^p \theta_{it}^c + \gamma_{ch,t}^k \delta_{e,t}^h \theta_{it}^c + \gamma_{ph,t}^k \left(\delta_{e,t}^h \theta_{it}^p + \delta_{e,t}^p \theta_{it}^h \right). \end{aligned} \tag{C.7}$$

Differentiating the future skill $\theta_{i,t+1}^k$ with respect to the current mother's mental health θ_{it}^h and with respect to the parental investment θ_{it}^p we obtain that the marginal effects of each are given by

$$\frac{\partial\theta_{i,t+1}^k}{\partial\theta_{it}^h} = \gamma_{h,t}^k + 2\gamma_{hh,t}^k \theta_{it}^h + \gamma_{ch,t}^k \theta_{it}^c + \gamma_{eh,t}^k \theta_{it}^e + \gamma_{ph,t}^k \theta_{it}^p, \tag{C.8}$$

$$\frac{\partial\theta_{i,t+1}^k}{\partial\theta_{it}^p} = \gamma_{p,t}^k + 2\gamma_{pp,t}^k \theta_{it}^p + \gamma_{cp,t}^k \theta_{it}^c + \gamma_{ep,t}^k \theta_{it}^e + \gamma_{ph,t}^k \theta_{it}^h. \tag{C.9}$$

respectively.

The effect of incidence of IPV $q_{it} = 1$ versus no IPV $q_{it} = 1$ on next period skill $\theta_{i,t+1}^k$ for $k = c, e$ including through indirect effects via inputs θ_{it}^k for $k = p, h$ is given by

$$\Delta\theta_{i,t+1}^k = \alpha_{q,t}^k + \frac{\partial\theta_{i,t+1}^k}{\partial\theta_{it}^p} \delta_{q,t}^p + \frac{\partial\theta_{i,t+1}^k}{\partial\theta_{it}^h} \delta_{q,t}^h. \tag{C.10}$$