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Exposure to Intimate Partner Violence and Children's Dynamic Skill Accumulation: Evidence from a UK Longitudinal Study

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Abstract

Children are increasingly recognized as secondary victims of intimate partner violence. This paper uses a unique UK longitudinal child development survey to study the relationship between verbal and physical abuse experienced by mothers and children's development up to the age of seven. Estimating production functions for cognitive, social, and socio-emotional skills we find that exposure during pre-school years has a quantitatively important negative effect on socio-emotional skills among toddlers and negatively affects cognitive and social skills after age three. The estimated impact on cognitive development is consistent with measures of cognitive skills based on school-based tests.

Keywords: Domestic violence, child development, skills, ALSPAC

JEL Classification: I14, I24, J12

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I Introduction

Evidence from high-income countries shows that up to a quarter of adults report exposure to Intimate Partner Violence (IPV) during childhood (Gilbert et al., 2009). In the UK, 7.9% of women (1.3 million) experienced domestic abuse in 2018, a relatively stable rate since 2009 (ONS, 2018). The awareness around this type of crime – and consequently the willingness to report abuse to the police – is rising: the number of reported domestic abuse increased of 23% between 2017 and 2018, with 599,549 cases recorded by the police in 2018, corresponding to 14% of all crimes.[1]

An extensive literature in psychiatry documents the negative impacts of IPV on victims' physical and mental health, including depressive symptoms, post-traumatic stress disorder and anxiety (Graham-Bermann and Miller, 2013; Pico-Alfonso et al., 2006). IPV has – since the 1970s – been widely studied in sociology and criminology as well.[2] The past decade has also seen a growing literature on IPV in economics, mainly focusing on understanding the determinants of IPV, including cultural and economic factors (Aizer, 2010; Anderberg et al., 2016; Card and Dahl, 2011; Tur-Prats, 2019), with more limited research on how women navigate and make decisions when facing abuse (Anderberg et al., 2018).

In addition to the detrimental effects of IPV on women as primary victims, children can be considered secondary victims when witnessing IPV (Anderson and Van Ee, 2018) – with exposure to IPV increasingly being recognized as a child maltreatment (Wathen and MacMillan, 2013). Parental abuse is a major stress factor within the household which can affect the development of the child. A literature in paediatrics documents a disadvantage in the socio-emotional development of children exposed to IPV, manifesting trauma symptoms, behavioural and psychosocial problems such as anxiety, depression, low self-esteem, attention difficulties and problems in interpersonal relationships (Devaney, 2015; Jouriles et al., 2001). Only a small number of contributions in economics have looked at the effect of IPV on children's outcomes and the attention has mostly been on health outcomes such as birth-weight, general health (Aizer, 2011; Currie et al., 2018; Jofre-Bonet et al., 2016) and mortality (Rawlings and Siddique, 2018).

With IPV being an important stressor within the household, exposure to IPV in early childhood may affect also the development of cognitive and socio-emotional skills during the critical

[1] The comparison between the administrative and the survey report reveals that a large proportion of victims of partner abuse do not report the abuse to the police, confirming that domestic abuse is an hidden crime. Therefore, administrative records provide only a partial representation of the actual level of abuse within the household.

[2] See for instance Black (2012) and Dobash and Dobash (2001).

development phase, characterized by rapid brain development and malleability (Currie and Almond, 2011). This in turn implies that such exposure can potentially have long-term consequences on labour, health or crime outcomes (Heckman et al., 2006).

Children's skills are shaped both by genetics and by environmental factors (Almlund et al., 2011; Borghans et al., 2008; Cunha and Heckman, 2007). Various environmental factors have been considered in the literature. Parental time investment and parenting style have received particular attention given the importance of parent-child interactions.[3] A potential negative environmental factor that has been extensively studied in economics as well as in sociology is parental divorce (McLanahan et al., 2013; Moroni, 2018; Mullins et al., 2015; Piketty, 2003), with some research pointing in the direction of a role played by parental conflict (Moroni, 2018; Tartari, 2016).

The aim of the current paper is to investigate the relationship between exposure to IPV and children's cognitive and socio-emotional development. We adopt a dynamic focus – measuring the timing of exposure – as the development of various skills may be affected differently by IPV in different stages of childhood. We draw on and combine elements from the different literatures outlined above: the psychology/paediatric literature - documenting a negative association between IPV exposure and behavioural and emotional problems, and the child development literature in economics – modelling the skill accumulation process – with the aim of furthering the understanding of the dynamic relationship between IPV exposure and child development.

We use data from the Avon Longitudinal Study of Parents and Children (ALSPAC), a cohort survey of children born in the former county of Avon in the UK between April 1991 and December 1992. We focus on data collected from the time of pregnancy up until the survey children are aged seven. Over this period, ALSPAC contains measures of verbal and physical abuse, rich data on parental and household characteristics, along with a wide range of children's cognitive and socio-emotional abilities.

We estimate a child development production function across seven sequential periods, covering age-in-months 0-6, 7-18, 19-30, 31-42, 43-57, 58-69, 70-81, where we follow the approach introduced by Todd and Wolpin (2003, 2007) and recently adopted by Fiorini and Keane (2014) and Del Bono et al. (2016) among others. The dynamic approach adopted is line with the recent literature on the technology of human capital formation (Cunha and Heckman, 2007, 2008;

[3]Examples of recent contributions can be found in Fiorini and Keane (2014), Del Bono et al. (2016), Agostinelli and Sorrenti (2018), and Moroni et al. (2019).

Cunha et al., 2010) which shows that parental inputs in each stage affect the production of child's abilities in the same stage, which, in turns, beget abilities at later stages and affect the productivity of future inputs. Our focus is on IPV – a negative input which can influence the dynamic development of children's skills. We implement several specifications of value-added models to estimate the effect of IPV at different stages of childhood and to identify sensitive periods, i.e. stages of childhood where IPV is more detrimental for certain domains of child's human capital.

In line with previous research on the impact of parental inputs on child development, our results confirm that the early years are a critical development phase for children. We find that IPV exposure is most harmful in early childhood, and especially for socio-emotional skills. We find that early exposure negatively affects the accumulation of cognitive and social skills around the time of starting school. This finding of cognitive skills is corroborated using matched school-based outcome measures.

The paper is organized as follows. Section II outlines the ALSPAC data, provides details of the sample and of the measures of the incidence of IPV and children's skills. It also provides some initial descriptives on the relationship between IPV and skills development. Section III outlines the empirical framework that we use. Section IV presents the core results on the joint dynamics of IPV exposure and children's skills development. Section V provides additional evidence that make use of school-based measures of cognitive skill. Section VI discusses mechanisms. Section VII concludes.

II Data

The Avon Longitudinal Study of Parents and Children (ALSPAC), also known as "Children of the 90s" is a local UK child development study conducted in the former England county of Avon. The target population for the ALSPAC study were pregnant women with estimated delivery dates between April 1991 and December 1992.[4]

The study is extremely rich in terms of home environment and child development as the recruited mothers were asked to complete questionnaires about themselves ("mother-based" questionnaires) and about the study child ("child-based" questionnaires).[5] Additional data

[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/

[5]Partners were also asked to complete questionnaires and, from the age of seven, the study child would

were collected in "clinics" and by matching external data sources (Boyd et al., 2013).

For the purpose of studying exposure to IPV and child-development, ALSPAC is an internationally unique resource. In this paper we exploit the fact that the mother-based questionnaires asked the ALSPAC mothers, roughly annually, about key events in their lives, including their experience with IPV, from pregnancy up until when the survey child was about 6 years old. We further take advantage of the child-based questionnaires providing repeated measures of children's skills development, covering cognitive-, social-, and socio-emotional skills. Finally, we make use of the linkage between ALSPAC and UK administrative data on the school-based test score from the National Pupil Database.

Baseline Birth and Mother Characteristics

The initial ALSPAC sample consists of 14,541 pregnancies.[6] We exclude twins and triplets (199 pregnancies in total). We drop cases with missing information on mother's age and/or qualification (1,630 cases). We further drop all women who did not respond to the first post-birth mother-based questionnaire (1,412 cases). Moreover, we exclude all observations with missing information on abuse, birth and/or partnership status (1,371 women) and any observations after the first missing observations. Our final sample contains 9,929 mothers who are observed on average for 6 periods. Table 1 provides baseline demographics of the births and of the mothers. The first column shows that the ALSPAC children weighted on average 3.4 Kg when born and had an average gestation period of 39.5 weeks; 48.4 percent were girls with an average birth parity of 0.8.[7] At the baseline survey – when they were around 32 weeks pregnant – the mothers' average age was 28 and close to 96 percent of mothers lived with a partner. We split the mothers' academic qualification levels into three similar-sized categories: "low", "medium" or "high".[8]

themselves compete additional questionnaires ("child-completed" questionnaires).

[6] This is the number of pregnancies for which the mother enrolled in the ALSPAC study and had either returned at least one questionnaire or attended a clinic by July 1999.

[7] In our sample, 45 percent of the children were first-born. Among those not first-born, the average number of previous births was 1.4.

[8] In England, traditionally the first academic qualification is gained at age 16. In the past, this age-16 qualification would be either a basic Certificate of Secondary Education (CSE) or the more academically challenging O-level qualification. The CSE and the O-level were replaced by the General Certificate of Secondary Education (GCSE) in 1988. In the GCSE system grades A-C are considered as "good pass" and lead to a higher level qualification than the low grades D-G. The majority of ALSPAC parents would have turned 16 before the introduction of the GCSE system and would in most cases have either a CSE or O-level qualification. The next level qualification is the A-level (Advanced level) gained at age 18, and which is the standard qualification for university entry. We define "low" academic attainment as either no academic qualification, a CSE, or a low GCSE (grades D to G).

Table 1: Baseline demographic characteristics of births and mothers

Birth		**Mother**	
Birth Weight (1,000gr)	3.426	Mother's Age	28.109
	(0.538)		(4.656)
Female	0.484	Partner	0.958
	(0.500)		(0.201)
Gestation Per.	39.467	Low Ac. Qual.	0.267
	(1.846)		(0.443)
Birth Parity	0.789	Medium Ac. Qual	0.361
	(0.902)		(0.480)
		High Ac. Qual.	0.371
			(0.483)
	N = 9,929		

Notes: The sample population are women and their ALSPAC-births. See text for details of sample selection. The left column provides information in relation to the birth of the ALSPAC study child. The right column provides information about the mother at baseline ($t = 0$), including her age, whether she lives with a partner (married or cohabiting), and her educational attainment. See main text for details. Standard deviations in parenthesis.

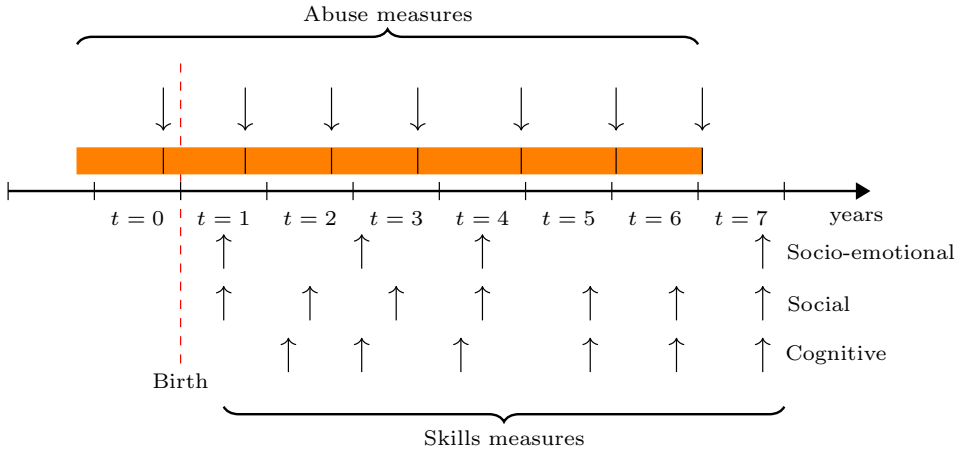
Longitudinal Structure

The longitudinal data used for our analysis stretches from pregnancy to when then child is approaching age 7. As the mother-based questionnaires were administered separately from the child-based ones, the IPV measures and the child-development measures do not coincide exactly in time. Moreover, the IPV measures asks the mother about abuse experienced over the past 12 months (or since she was last asked), whereas the child-development measures refer to current skills.

Figure 1 describes the timeline of the longitudinal data used below. We will label time as $t = 0, 1, ..., 7$ where $t = 1$ is used to represent the child's first year etc., and $t = 0$ represents the year leading up to birth. The mother-based surveys measuring incidence of IPV took place first mid-pregnancy, and then after birth, when the child was 8, 21, 33, 47, 61 and 73 months old respectively. The timing of the mother-based questionnaires are indicated by the arrows above the timeline. The orange block-segments indicate the time period. The child-based

We define "medium" academic attainment as an O-level or a high GCSE (grades A-C). Finally, we define "high" academic attainment as A-level, undergraduate or postgraduate degree.

questionnaires used to measure the child's skills was administered when the child was aged 6, 15, 18, 24, 30, 39, 42, 57, 69, and 81 months, though not all skills are measured at each of these points in time.



Notes: The figure illustrates the timing of measurements of abuse and skills relative to the time of birth of the ALSPAC child. Skills are measured *at* a given moment in time. The IPV measures, in contrast, indicate experience of abuse *over* a period of time, highlighted by the orange block-segments.

Figure 1: Timeline of the data

Next we will describe the measures of IPV and skills respectively, and provide descriptive statistics.

Physical and Emotional Abuse

The indicators of abuse used in the current analysis are based on a recent events inventory included in the mother-based questionnaires from pregnancy through to when the study child was six years old. Two recurrent items were "Your partner was physically cruel to you" and "Your partner was emotionally cruel to you". We will take these self-reported measures at face value and, for the majority of the analysis, we will combine the two into a single indicator of "any partner abuse". 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 in terms of demographic correlates – to the best available measures in the UK based on the British Crime Survey (ONS, 2018).

For the 9,929 ALSPAC mothers we have a total of 59,628 observations measuring IPV incidence over time. Table 2 shows the average observed incidence of physical and emotional abuse. Overall, the average observed incidence of physical and emotional abuse is 2.5 and 8.9

Table 2: Incidence of emotional and physical abuse

		Physical		
		No	Yes	Total
Emotional	No	0.906	0.005	0.911
		(0.001)	(0.000)	(0.001)
	Yes	0.069	0.020	0.089
		(0.001)	(0.001)	(0.001)
	Total	0.975	0.025	N=59,628
		(0.001)	(0.001)	

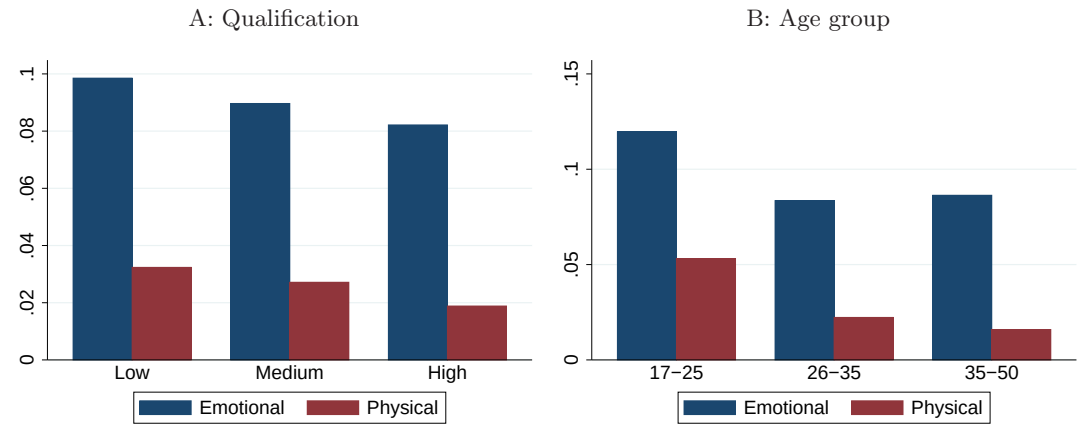
Notes: The unit of observation is a mother-year for the ALSPAC sample of 9,929 mothers, observed between pregnancy ($t = 0$) and the ALSPAC child becoming six years old ($t = 6$). The maximum number of observations per mother is seven and the average number of observations is 6.0. See text for definitions of the abuse measures. Standard errors in parenthesis.

percent respectively. As there are very few reports of physical abuse without emotional abuse, we combine the two and find that the average incidence of any abuse is 9.4 percent.

Figure 2 highlights how the two categories of abuse varies with mother's education and age. In line with evidence from the British Crime Survey, we find that abuse incidence decreases with educational attainment and with age.

Figure 3 provides different perspectives on the dynamic pattern of abuse observed in the data. The top left panel shows measured incidence of any IPV *at* and *by* time t respectively. Focusing first at abuse *at* time t, two features stand out: (i) reported abuse increases substantially after birth, and (ii) after birth, abuse declines gently over time. The abuse *by* time t increases gradually up just over 25 percent. Hence, by the time the study child is aged 6, just over a quarter of mothers have – since entering the study – reported some form of abuse at some point in time. These findings provide a first indication that IPV incidence is highly persistent over time and suggest that it is often the same mothers experiencing abuse repeatedly over time.

To highlight this further, the top right panel shows the count distribution for number of periods that a mother reports experiencing abuse. About three quarters of the ALSPAC mothers report no abuse at all and are left out of the figure. The figure then shows that 12.5 percent of women report abuse in exactly one period; a further 6 percent do so in two periods, a further 6.5 percent report abuse in 3 or more periods. The shape of the count distribution is again indicative of a high degree of persistence of IPV.



Notes: The figure illustrates the incidence of emotional and physical abuse by mother's qualification (Panel A) and age (Panel B), pooling across all observations in the data. See Section II for the definition of the qualification categories.

Figure 2: IPV exposure by qualification level and age group

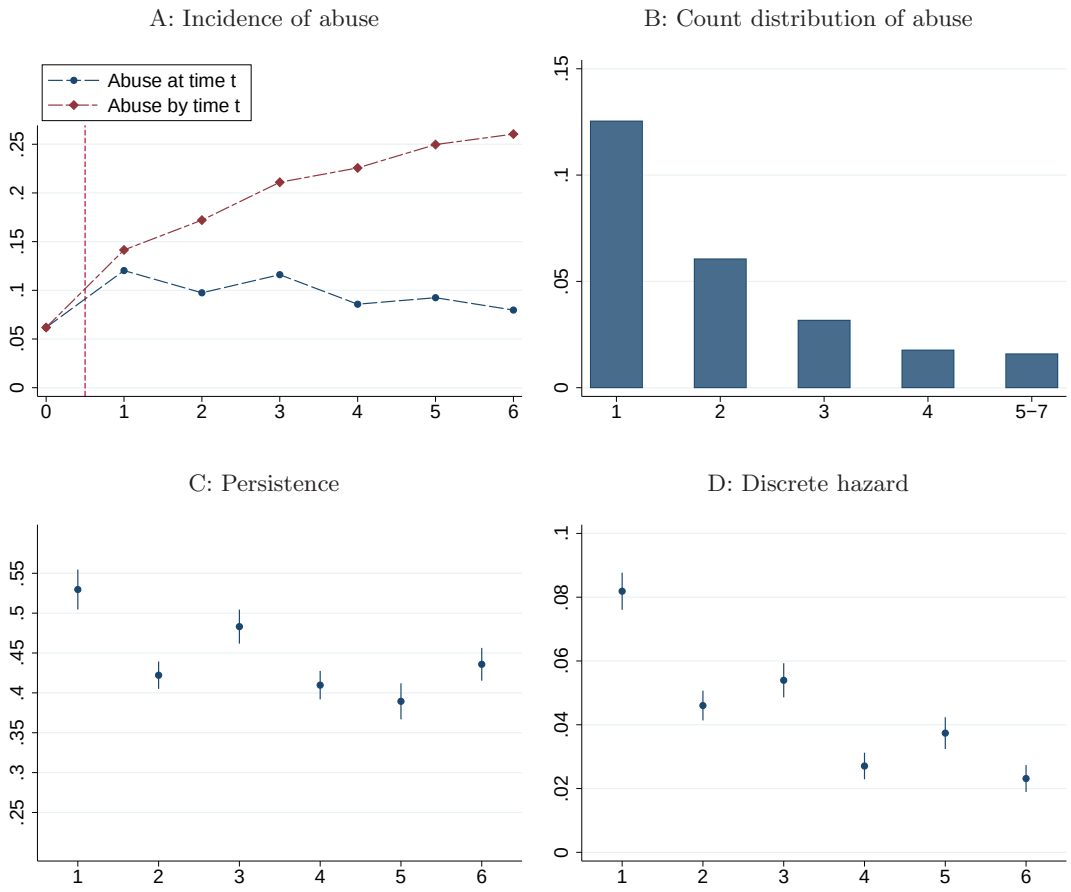
The very strong persistence of abuse over time is illustrated in the bottom left panel. The figure plots the coefficients from regressing the abuse indicator at time t on the corresponding indicator for having experienced abuse at time $t-1$. The figure shows that a woman who reported abuse at time $t-1$ is, on average, around 45 percentage point more likely to report abuse at time t than is a woman who did not report any abuse at time $t-1$. Overall, this means that the risk of abuse for a woman who experienced abuse in the previous period is about 10 times higher (about 0.5) than for a woman who did not experience abuse in the previous period (about 0.05).

Finally, we can consider how the likelihood of reporting abuse *for the first time* varies over time. That is, at each time t we measure the proportion of women reporting abuse among those who, up to time $t-1$, had not reported any abuse. The bottom right panel shows that this "onset hazard" declines sharply over time, indicating that only relatively few women report abuse for the first time when the child is aged 4 and above.

Skill Measures

We will consider three different skill-categories: cognitive, social, and socio-emotional skills. Here we provide a broad overview of each measured skill category. Details of the skill measures used are provided in the Appendix.

Cognitive Skills: As illustrated in Figure 1, measures for cognitive skills are available when the child is aged 15, 24, 38, 57, 69, and 81 months. The first three measures are age-appropriate



Notes: Panel A illustrates the incidence of any IPV (either emotional of physical abuse) *at* and *by* time period relative to the birth of the ALSPAC child (indicated by the vertical red line). Panel B shows the distribution of the number of periods (out of the seven sample periods) in which the mother reported experiencing any abuse (with a zero count not shown). Panel C shows the estimated persistence of abuse, $Pr(a_{i,t} = 1|a_{i,t-1} = 1)$. Panel D shows the estimated hazard for first reporting abuse at time t, $Pr(a_{i,t} = 1|a_{i,\tau} = 0 \text{ for all } \tau < t)$.

Figure 3: The dynamic pattern of abuse

versions of MacArthur-Bates Communicative Development Inventories (CDIs) which capture information about children's abilities including vocabulary comprehension, production, gestures, and grammar (Fenson et al., 2007). For the latter three measures, the ALSPAC study retained the focus on vocabulary and grammar from MacArthur-Bates whilst incorporating measures of numerical skills.

Social Skills: As shown in Figure 1, measures for social skills are available when the child is aged 6, 18, 30, 42, 57, 69, and 81 months. The first four measures are age-appropriate versions of the Denver Development Screening test (DDST) focusing mainly on aspects of socialisation inside and outside the home: e.g smiling, playing, feeding, drinking himself and shyness (Frankenburg and Dodds, 1967). For the latter three measures, further elements related to socialization with

other children, such as playing, sharing and empathy are included.

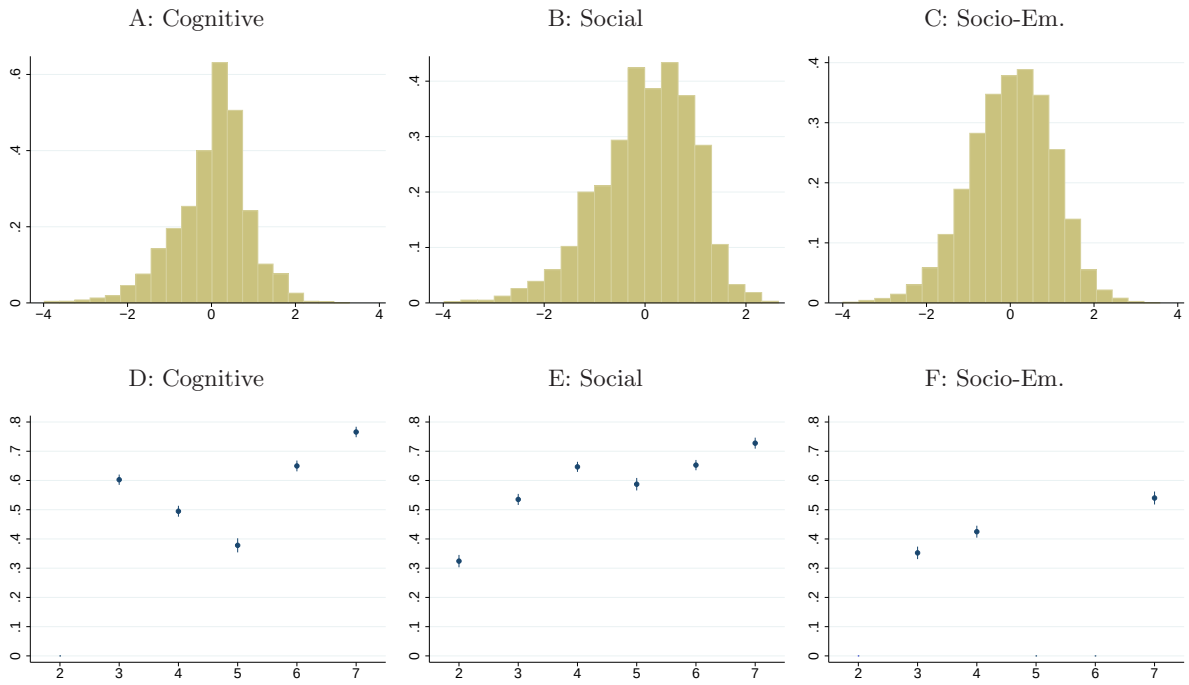
Socio-Emotional Skills: As described in Figure 1, measures for social skills are only available when the child is aged 6, 24, 42, and 81 months. The first two measures are versions of the Carey Infant Temperament (CIT) questionnaire measuring activity, rhythmicity, approach, adaptability, intensity, mood, persistence, and distractibility (Carey and McDevitt, 1977). The latter two measures use the well-known Strengths and Difficulties Questionnaire (SDQ) – which is generally considered to be applicable between age 3 and 16 – measuring emotional problems, peer problems, conduct problems, hyperactivity disorder and pro-social behaviour (Goodman, 1997).

Each measures is normalized, period-by-period, to have zero mean and unit standard deviation. Figure 4 shows the distribution and persistence of each skill. The top row of panels shows the histogram for each skill measure – pooled across all periods. Each skill has a smooth – somewhat left skewed – distribution. Skills are naturally highly persistent over time. This is highlighted in the bottom row of panels in Figure 4. Each panel plots the coefficients from regressing each skill measure at time t on the most recent previous measure of the same skill. In most cases, a standard deviation higher score on the most recent skill measure is associated with at least half of a standard deviation higher score at present.

Table 3 shows how the earliest measure of each skill is associated with the baseline birth and mother characteristics. Most coefficients are in line with what would be expected from the literature. For instance, higher birthweight, longer gestation period, mother's academic qualification and lower birth parity is positively associated with skills. As expected, girls outperform boys in cognitive and social skills. Although girls seem to have lower socio-emotional skills then boys when considering the earliest measures, the pattern is reversed and consistent with the other skills when considering socio-emotional skills later in life.

Association between Skills and Past and Future Abuse

Before proceeding to the modelling of the skill accumulation process, we will provide a descriptive analysis of how measured skills are related to the exposure to abuse. To do so, we regress each skill measure on an indicator for the mother reporting some abuse at any point in time before the particular skill measure. For instance, for cognitive skills measured at 24 months, we regress this measure on an dummy that indicates whether the mother reported abuse either in pregnancy,



Notes: Panels A-C illustrate the distribution of the (normalized) cognitive, social and socio-emotional skill measures pooled across all available observations. Panels D-F illustrate the "persistence" of each skill by regressing the skill measure at time t on its most recent lagged value. The bars indicate 95 percent confidence intervals.

Figure 4: Skill distributions and persistence

or at 8 months, or at 21 months.[9]

The results are reported in Figure 5. Interestingly, for each measure there is no negative association between the mother experiencing abuse and child skills at a very young age. For cognitive and social skills there is a negative association emerging after age 4. The largest association is observed for socio-emotional skills where a negative association emerges both earlier and stronger.

A key concern with these measured associations is that they may simply reflect unobserved family characteristics that are associated with both abuse and worse skill outcomes. Similar concerns have long plagued the literature on the relationship between divorce and children's outcomes. In that context, Piketty (2003) used longitudinal data to show that children to parents who have not divorced yet, but will do so in the future, have worse outcomes well before the divorce actually occurs, thus casting doubt on any causal interpretation. Figure 6 looks at whether the same issue applies in our case. The figure plots the coefficients from regressing each skill measure on a dummy for the mother reporting abuse in the future within the subsample of

[9]This thus misses any first abuse happening between the age of 21 and 24 months.

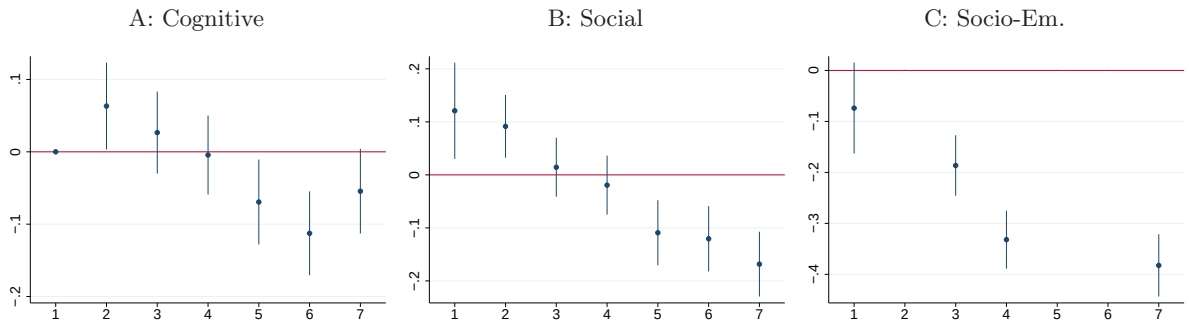
Table 3: Relationship between initial skills and baseline characteristics

	(1) **Cognitive**	(2) **Social**	(3) **Socio Em.**
Birthweight (1,000gr)	0.056**	0.097***	0.039
	(0.023)	(0.024)	(0.024)
Female	0.347***	0.049**	-0.083***
	(0.020)	(0.021)	(0.021)
Gestation Per.	0.045***	0.069***	0.017**
	(0.007)	(0.007)	(0.007)
Birth Parity	-0.026**	-0.024*	-0.075***
	(0.012)	(0.013)	(0.013)
Mother's age	-0.037**	-0.146***	0.015
	(0.021)	(0.021)	(0.021)
Mother's Age Sq.	0.000	0.002***	0.000
	(0.000)	(0.000)	(0.000)
Partner	-0.039	0.004	0.044
	(0.049)	(0.056)	(0.056)
Medium Ac. Qual.	0.065**	0.034	0.028
	(0.027)	(0.028)	(0.027)
High Ac. Qual.	0.012	0.147***	-0.025
	(0.028)	(0.029)	(0.028)
N	9,076	8,557	9,130

Notes: The table presents regressions of the first observation of each skill category on baseline characteristics of the mother and the ALSPAC-birth. See Table 1 for details of baseline characteristics. Cognitive skills are measured at 15-months ($t = 2$) while social and socio-emotional skills are measured at 6 months ($t = 1$). See Figure 1 for the timing of skill-measurements and the appendix for details of the measures. Standard errors in parenthesis. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

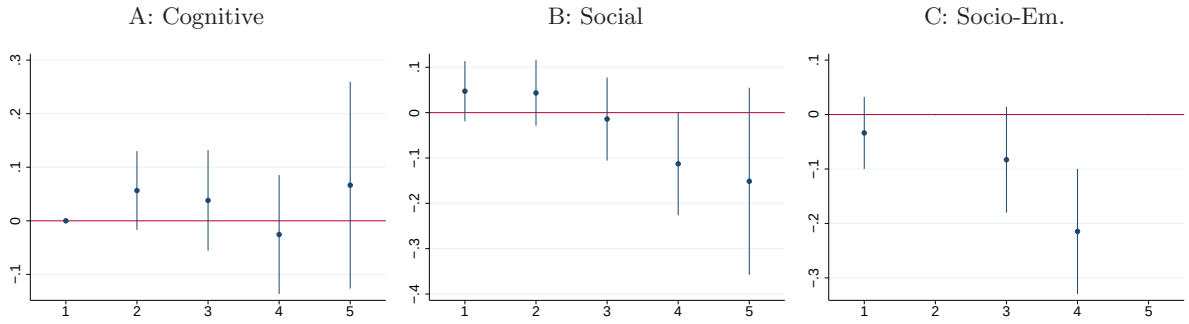
families where no abuse has been reported to date.[10] We find no association between cognitive skills and future abuse. For social and socio-emotional skills there is a suggestion of negative associations. However, as onset of abuse is rare after the child is aged 4 or higher, the statistical power also decreases rapidly with the age of the child.

[10]Note that, since the abuse questions look back over the previous 12-month period, each regression for skills measured at t conditions on no abuse being reported through to $t + 1$ and then regresses on a dummy for abuse being reported for a first time at some time $t + 2$ or later.



Notes: Panels A-C illustrate the association between child's skills as measured at time t and the mother having reported abuse at any point prior to time t. The bars indicate 95 percent confidence intervals. For details of the timing of measurements of skills and abuse, see Figure 1.

Figure 5: Relative skills by any past IPV exposure



Notes: Panels A-C illustrate the association between child skills as measured at time t and the mother reporting abuse at any future point (conditional on not having reported abuse at any time prior to t). The bars indicate 95 percent confidence intervals. For details of the timing of measurements of skills and abuse, see Figure 1.

Figure 6: Relative skills by any future IPV exposure

III Empirical Framework

We model child development as a cumulative process and we estimate production functions of cognitive-, social- and socio-emotional skills by following the empirical specification introduced by Todd and Wolpin (2003, 2007) and recently adopted by Fiorini and Keane (2014) and Del Bono et al. (2016).

Because we are mainly interested on the timing of exposure to abuse and how it affects child development, we model current child's skills as a function of the full history of abuse and past skills measures. Including past skills measures allows us to take into account omitted past inputs and unobserved ability and hence address potential endogeneity issues. To deal with the measurement error problem arising when including the lagged skill measure and avoid the attenuation bias of the lagged skill coefficient, we instrument it with the twice-lagged skill (Andrabi et al., 2011; Arellano and Bond, 1991). In our model, simultaneity is unlikely to occur

given that, as showed in Figure 1, the reported measure of abuse is recorded before the skills measures and refers to the past 12 months.

In the most general case we will use the following "cumulative value-added" (CVA) model for skill y of child i at time t,

$$y_{it} = \sum_{s=1}^{t} a_{i,t-s}\beta_{t-s} + X_i\gamma + \lambda y_{i,t-1} + \varepsilon_{it}, \tag{1}$$

where $a_{i,t}$ is a dummy for the mother reporting abuse at time t, and X_i are baseline birth- and mother-characteristics, and ε_{it} is a random error term. Hence, the general model includes both the complete path of abuse leading up to time t and baseline characteristics. The inclusion of the lagged skill measure serves the dual purpose of allowing for skill "self-productivity", whereby skills beget skills (Cunha and Heckman, 2007, 2008) and – as mentioned before – for omitted past inputs and unobserved ability.

Following Fiorini and Keane (2014) we will refer to the special case that excludes the lagged skill value ($\lambda = 0$) simply as the "cumulative model" (C). We will also estimate specifications where we replace the full path of abuse with a dummy indicating any past abuse reported by $t-1$ and refer to this simpler model as the simple "value-added model" (VA).

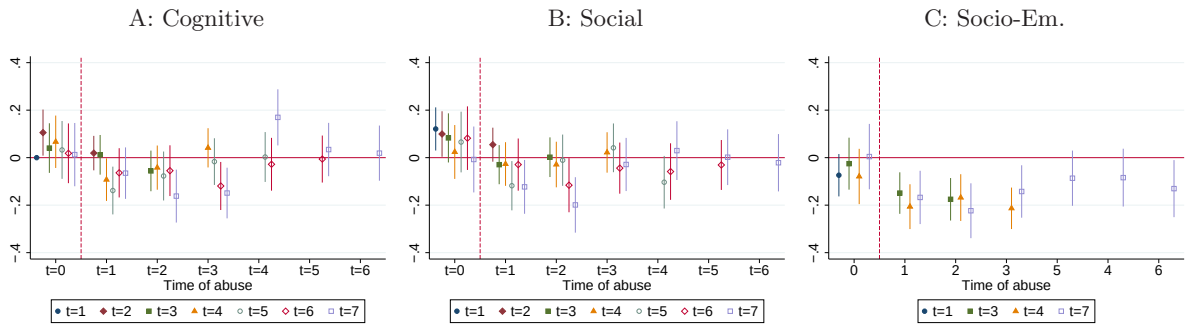
Following Del Bono et al. (2016) we will present specifications where we instrument for the lagged skill $y_{i,t-1}$ with the twice-lagged skill, $y_{i,t-2}$. This leads to CVA-IV and the VA-IV specifications where we take into account potential measurement error problems in the lagged skills, typically arising in value-added models.

IV Results

We start by presenting the results from estimating the cumulative models (C, CVA and CVA-IV), that is the models where we include the full path of reported abuse. After that we will consider the simpler specification which use only a single dummy for any previous abuse (VA-IV).

Cumulative Models

Starting with the simple cumulative model (C), Figure 7 plots – for each skill measure and time t – the coefficients on each earlier abuse report. For instance, for cognitive skills measured in the child's third year of life $t = 3$, the green squares – obtained from a single regression – plot the coefficients on abuse reported by the mother in pregnancy ($t = 0$), and in the child's first



Notes: Panels A-C illustrate the coefficients on past abuse from estimating equation (1) without including the lagged skill value (the "cumulative model"). The bars indicate 95 percent confidence intervals. The vertical red line indicates the time of birth.

Figure 7: Estimates from the cumulative model

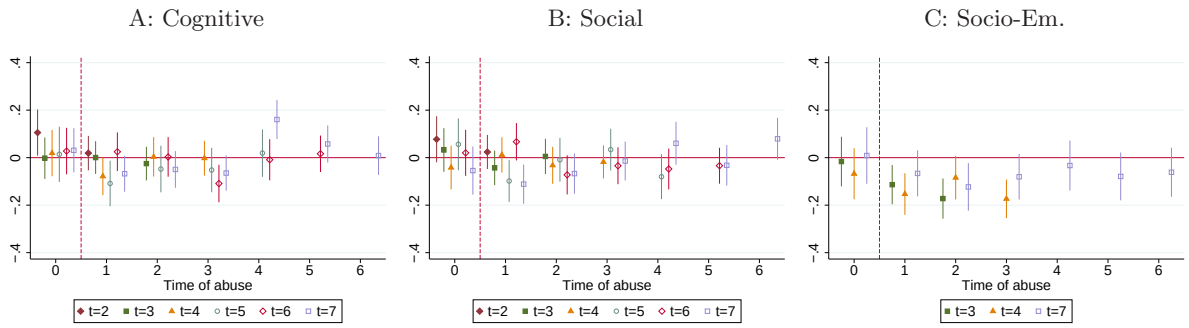
($t = 1$) and second year of life ($t = 2$) as indicated on the horizontal axis.

Three key patterns emerge from the C-model. First, there is no significant negative association between abuse reported in pregnancy and any measurement of the child's skills. This is a finding that will carry over also to the CVA and CVA-IV models presented below. Hence, we consider this to be a robust finding.

Second, for each of the three skill categories, abuse reported by the mother in the child's first three years of life is negatively associated with multiple measures of that skill. Indeed, for socio-emotional skills abuse reported at $t = 1, 2, 3$ is negatively associated with each subsequent measure. This suggests that exposure to abuse early in life – before age 3 – is negatively associated with the child's subsequent skills.

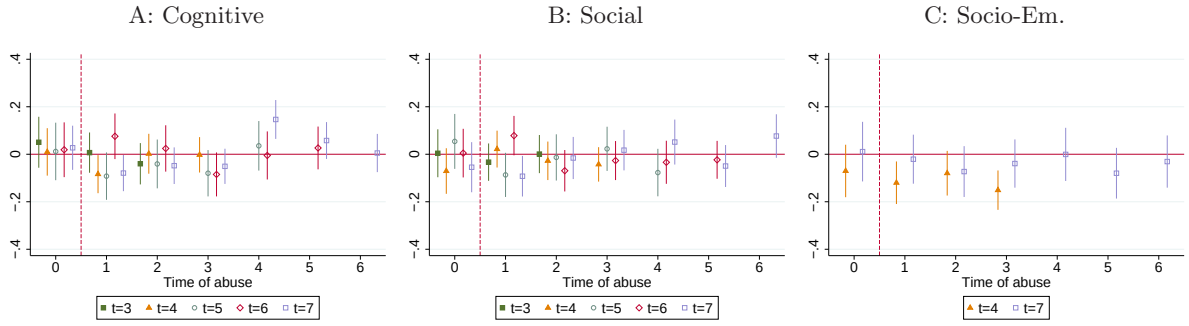
Third, there is - bar one exception – no negative association between abuse reported after the child is aged 3, that is at $t = 4, 5, 6$ and subsequently measured skills. Again, this is a pattern that will carry over to the CVA and CVA-IV models below. In interpreting this finding it should be borne in mind that the persistence of abuse is high and, as noted above, abuse rarely occur for a first time after age 3. Hence, abuse at age 4 or higher is typically associated also with abuse having occurred in the child's first three years of life. In this sense, the lack of significant negative effects indicate that additional abuse occurring after age three has no additional negative effect.

Figure 8 plots the corresponding coefficients from estimating the CVA specification. This specification thus controls for the lagged value of the same skill, which of course means that we cannot estimate this specification for the initial measure of each skill. Controlling for the lagged skill value naturally tends to make the estimated coefficients smaller. As noted, we still find



Notes: Panels A-C illustrate the coefficients on past abuse from estimating equation (1). The bars indicate 95 percent confidence intervals. The vertical red line indicates the time of birth.

Figure 8: Estimates from the cumulative value-added model



Notes: Panels A-C illustrate the coefficients on past abuse from estimating equation (1) while instrumenting for the lagged skill value with the twice lagged skill value. The bars indicate 95 percent confidence intervals. The vertical red line indicates the time of birth.

Figure 9: Estimates from the cumulative value-added IV model

no negative association between abuse reported either in pregnancy or after age 3 and skills: as before, only abuse reported in the child's first three years of life is negatively associated with measures of the child's skills. Interestingly, for cognitive and social skills, the negative association of early exposure to abuse is observed for later skill measures – after age 4. In contrast, the negative association between early exposure to abuse and socio-emotional skills appear to be more contemporaneous, with the largest effects on those measured for $t = 3$ and $t = 4$.

Figure 9 plots the corresponding coefficients from estimating the CVA-IV specification. This specification instruments for the lagged skill value with the twice lagged skill value, whereby we can only estimate this specification starting at the third measure for each skill. The estimated coefficients become slightly less precise, but generally change marginally in magnitude, this leaving the same overall pattern.

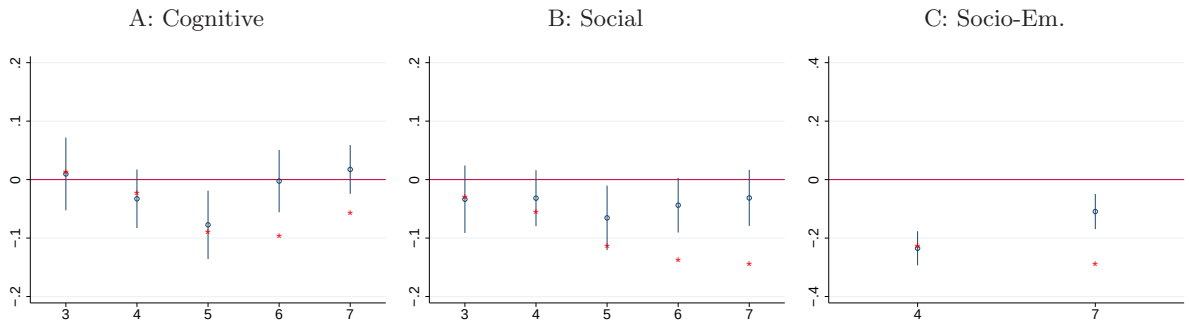
Value-Added and Any Past Abuse

The high degree of persistence of abuse implies that abuse indicators in the cumulative models are highly correlated, making it challenging to pinpoint the impact of abuse at a particular point in time on skills at some particular future point in time. In order to focus more specifically on the timing of impact, we estimate here simplified versions where the path of past abuse is replaced by a single binary indicator for any past abuse. However, compared with the simple descriptive associations in Figure 5, we control for the lagged skill value (value-added models) and baseline characteristics. Furthermore, we instrument for the lagged skill value with the twice-lagged value, implying that we can estimate these models only starting at the third observed measure for each skill.

Figure 10 plots the estimated coefficients. For cognitive skills we find that the impact of past abuse occurs particularly around school-starting age, that is in the child's 5th year of life ($t = 5$), but not in the following two years. For social skills we similarly find that the effects of abuse appear to be concentrated around school-starting age. In contrast, for socio-emotional skills the estimated effects are in line with the findings from the cumulative models: we find the largest effect for $t = 4$, that is, when the child is still only aged 3 and still not in school-age.

As an exposure to abuse means that the child will remain in the "ever-exposed" state throughout their childhood. The above simple model can therefore be used to compare the predicted skill path of a child who is exposed to abuse early in life – e.g. in the first year of life – to that of an otherwise identical child who is never exposed. The results from this exercise – which uses both the estimated impacts at each age and the estimated skill-persistence – are shown in red markers. For cognitive skills, this exercise suggest that the effect that occurs around school-starting age implies that the child exposed to abuse fall behind by about 0.1 standard deviation, with some recovery in the following two years. For social skills, a similar-sized effect is predicted at school-starting age but with no indication of recovery in the following two years. Finally, for socio-emotional skills, the predicted effects are both larger and appear earlier.

As these predictions use the estimated skill persistence to create a predicted cumulated effect by time t, the predicted effects highlighted in Figure 10 are directly comparable to the simple descriptive effects shown in Figure 5 above. Indeed, for cognitive and social skills, the predictions from the VA-IV model is strikingly similar to simple descriptive association, both in terms of level of effect and time-pattern. For socio-emotional skills, the predicted effects – both at time $t = 4$ and $t = 7$ – are smaller than suggested by the corresponding descriptive statistic.



Notes: Panels A-C illustrate the coefficients on past abuse from estimating equation (1), replacing the full path of abuse with a dummy indicating any abuse along the path up to the time of the skill measurement. The lagged skill value is instrumented with the twice lagged skill value. The bars indicate 95 percent confidence intervals. The red markers indicate cumulative effects. The vertical red line indicates the time of birth.

Figure 10: Estimates from the value-added IV model

V Additional Findings

School-Based Measures of Cognitive Skills

The above analysis used measures of abuse and child skills that were both reported by the mother (albeit never at the same time). A potential concern with this is that the mother's who experience abuse are likely to perceive their own situation in a negative light and may project negativity onto the child when reporting on skills. Such reporting effects would lead to over-estimated effects of abuse.

For this reason it is useful to consider skill measures that are not based on mother-provided reports. To this end, we make use here of linked data from the National Pupil Database on Entry Assessments (EA) and SATS.

EAs of children starting school are only currently being introduced into the national assessment structure in England.[11] However, various local versions of EAs have long been used by several local authorities for benchmarking purposes. Fortunately, EAs were not only used by, but also coordinated across, the four Local Education Authorities (LEA) that covered the former Avon area at the time when the ALSPAC study children entered school.[12] These EA test scores have been linked onto the ALSPAC data. At the end of Key Stage 1 (toward the end of Year 2), the ALSPAC children took the national test and the results from there have also been linked in. The EA assessments covered language, reading, writing and mathematics skills.

[11] The so-called "Reception Baseline Assessment" was piloted in 2018, voluntary for schools in 2019, and due to be made compulsory in 2020.

[12] The four LEAs were Bristol, South Gloucestershire, Bath and North East Somerset, and North Somerset.

Similarly, the SATS tests measured reading, writing and mathematics skills. This means that these tests measure skills that correspond to the cognitive skill measures used above, with the EA test being close in time to the $t = 5$ cognitive skill measure, and the SATS measure being close in time to the $t = 7$ cognitive skill measure.[13] We use latent factor analysis to combine the EA tests scores into a single normalized score and do the same for the SATS.[14]

Table 4: Comparing the survey-based measures of cognitive skill to school entry assessment and SATS test score outcomes

	Cogn. Skill, $t = 5$	Entry Assessment	Cogn. Skill, $t = 7$	KS1-SATS
Panel A: Pairwise Correlations				
Cogn. Skill, $t = 5$	1	0.328	0.504	0.418
Entry Assessment		1	0.360	0.602
Cogn. Skill, $t = 7$			1	0.482
KS1 SATS				1
Panel B: Relative Outcome by Any Past IPV Exposure				
	Cogn. Skill, $t = 5$	Entry Assessment	Cogn. Skill, $t = 7$	KS1-SATS
Past Abuse	-0.069**	-0.097***	-0.054*	-0.124***
	(0.030)	(0.034)	(0.030)	(0.033)
N	6,518	4,700	5,599	4,730
Panel C: Value Added Effect of Any Past IPV Exposure				
			Cogn. Skill, $t = 7$	KS1-SATS
Past Abuse			-0.037	-0.071**
			(0.026)	(0.031)
N			4,903	3,472

Notes: Panel A shows correlations between the ALSPAC-based measures of cognitive skills at time $t = 5$ (57 months) and time $t = 7$ (81 months) and the school-based measures from Entry Assessments and Key Stage 1 SATS. See Appendix for details of all skill measures. Panel B presents regressions of each measured cognitive skill level on an indicator for any past abuse experienced by the mother. Additional controls include all baseline variables presented in Table 1 (and mother's age squared). Panel C presents regressions of cognitive skills measured in period $t = 7$ on an indicator for any past abuse experienced by the mother while controlling for past skill. In the case of ALSPAC-based measure, the measure for past cognitive skill is the ALSPAC-based measure at $t = 5$. In the case of SATS, the measure for past cognitive skill is the Entry Assessment-based measure. Additional controls include all baseline variables presented in Table 1 (and mother's age squared). Standard errors in parenthesis. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Panel A of Table 4 shows the pairwise correlations between the survey-based cognitive skill

[13]Note, however, that unlike the skill measures used above, the children varied in age when taking the EAs and the SATS. In particular, the youngest children taking the EAs would have been just over four years old whereas the oldest children would be just over five. Similarly, when taking the SATS, the children would have been generally between six and a half and seven and a half years old.

[14]Details of the construction of these measures are provided in the Appendix.

scores at $t = 5$ and $t = 7$ and the two school-based scores. There is a strong positive correlation between the EA score and the skill score at $t = 5$ (0.33). Interestingly, the skill score at $t = 5$ is even more strongly correlated with the end-of-KS1 SATS outcome, but the latter is even more strongly correlated with the survey-based measure of cognitive skills at $t = 7$. This suggests that the EA-measure is more noisy than the SATS measure. There is nevertheless a very strong persistence between the EA and the SATS.

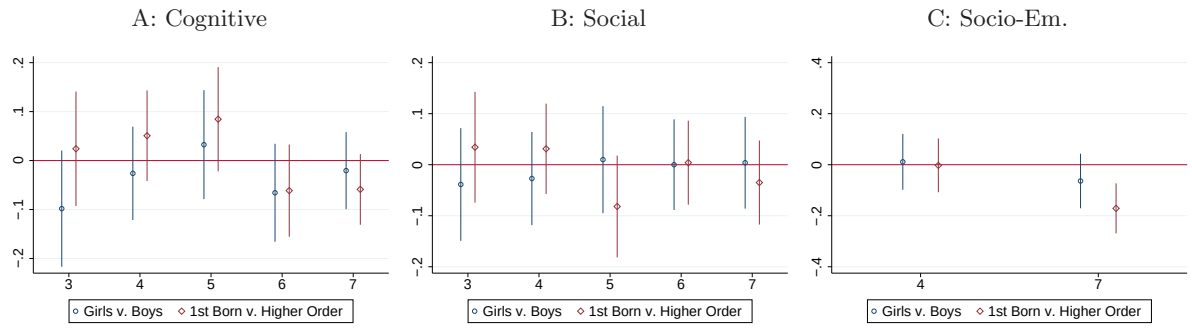
Panel B repeats the regressions for the cognitive skill measures highlighted in the left panel of Figure 5 (for $t = 5$ and $t = 7$) and also presents corresponding regressions for the EA- and SATS-scores.[15] If anything, we find that the association between any past exposure to abuse and skills is stronger when using the school-based measures than when using the mother-reported measures. Finally, in Panel C, we present the results of two value-added specifications: for cognitive skills at $t = 7$ we include as control the cognitive skill measure at $t = 5$ while for KS1-SATS measure we control for the EA-based measure (along with controls for baseline characteristics). Again, we find that the estimated effect of any previous exposure to abuse is stronger when using the school-based measure than when using the mother-reported measure. Hence, we find no indication that our results are driven by abuse-related biased reporting about the child's skills.

Heterogeneity by Gender and Birth Order

Here we explore potential heterogeneity in the impact of abuse by gender and birth order. To do so, we re-estimate the simple VA-IV model and include interactions to determined if the effect of past abuse is different for girls versus boys, and for first-born versus children of higher birth order. The results are highlighted in Figure 11 which plots the estimated coefficients on the interaction terms.

Panel A shows that there are no significant gender-differences in the effect of past abuse on cognitive skills at any age. Panels B and C show that the same is true to social- and socio-emotional skills. Overall, there is no particular gender pattern to the estimated effects, with the estimated gender-differences scattered fairly uniformly around zero. The same holds for the difference with respect to birth order with only one exception: the estimated negative impact of past abuse on socio-emotional skills is larger for first-born children than for higher birth-order children in the final period, that is at age 6.

[15] The regressions presented in Panel B thus control for baseline characteristics.



Notes: Panels A-C illustrate the coefficients on interactions between past abuse and (i) a gender-dummy, and (ii) a dummy for the child being first-born, when estimating equation (1) while instrumenting for the lagged skill value with the twice lagged skill value. The bars indicate 95 percent confidence intervals.

Figure 11: Gender and birth-order heterogeneity in the effect of past abuse as estimated by the value-added IV model

VI Mechanisms

The documented negative impact of IPV on child development can arise either directly, due to the child exposure to violence within the household - which might have a direct detrimental effect on child skills accumulation - or indirectly, through changing the home environment and in particular mother's behaviour as the primary victim of the abuse. In particular, the mother might react to the abuse by trying to protect herself and her child by changing e.g. her labour supply to escape from the home environment, or her style of parenting to compensate for the child exposure to a negative environment in the family. These changes, occurred as a response to the abuse, might mediate or exacerbate the effect of IPV on child development.

We explore several potential mechanisms whereby IPV might change (i) maternal choices, e.g. divorce or labour supply, and (ii) maternal behaviour e.g. mother's mental health and mother's time investment into the child. All these aspects can represent channels through which abuse onto mothers may affect child development.

In Table 5 we investigate how abuse relates to mother's decision to divorce (Panel A) and work full time (Panel B). Experiencing abuse is associated with 5.6 percentage points higher probability of divorcing in the following period, with similar magnitudes for physical and emotional abuse. With a baseline divorce rate of 1.8 percent, this means that the experiencing abuse quadruples the divorce rate. Nevertheless, the divorce rate still remains relatively low – the vast majority of women stay – even after experiencing abuse. In addition, mothers respond to abuse by increasing the probability of working full time of 5.3 percentage points. This evidence suggests that mothers react to IPV by trying to escape from the home environment by separating

Table 5: Potential mechanisms - Mother's choices

	Panel A: Divorce since t-1		
	(1)	(2)	(3)
Any abuse (t-1)	0.056***		
	(0.005)		
Physical abuse (t -1)		0.051***	
		(0.009)	
Emotional abuse (t-1)			0.058***
			(0.005)
Observations	42,370	42,370	42,370

	Panel B: Labour Supply - Working FT at t				
	(1)	(2)	(3)	(4)	(5)
Any past abuse	0.053***				
	(0.004)				
Any abuse (t)		0.024***	0.009		
		(0.005)	(0.006)		
Any abuse (t-1)			0.039***		
			(0.006)		
Physical abuse (t)				0.024**	
				(0.010)	
Emotional abuse (t)					0.024***
					(0.006)
Observations	40,332	40,332	40,332	40,332	40332

Notes: The dependent variable in Panel A is "divorce since $t-1$", defined living with a partner at $t-1$ but not at t. The sample is restricted to women living with a partner at $t-1$. The independent abuse variables indicate abuse reported by the mother at $t-1$, while she was living with a partner. The regressions further include controls for the baseline characteristics in Table 1. The dependent variable in Panel B is an indicator for working full-time at time t. The regressions control for labour supply status at time $t-1$ along with controls for the baseline characteristics in Table 1. Standard errors in parenthesis. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

from their partners or/and by increasing their labour supply.

In Table 6 we document how abuse is associated with mother's mental health (Panel A)[16] and mother time investment into the child (Panel B).[17] Both variables are normalized to have

[16]Mother's mental health problems are measured with the Edinburgh Postnatal Depression Scale (EPDS), constructed on the basis of questions on mother's symptoms of depression and anxiety. Further description of the EPDS variable can be found in the Appendix.

[17]The survey questionnaire asks the mother to report how frequently she baths, feeds, sings, reads, plays, takes the child for walk. Considering these questions we use latent factor models to construct an index of time investment, with higher values indicating higher the time investment. Further details on the creation of this

zero mean and unit standard deviation. Being abused markedly impacts mother's mental health, with abuse being associated with 60% of a standard deviation higher mental health problems for the mother. On the other hand, mothers tend to reduce, but only of around 1 percent of a standard deviation, their time with their children once they experience IPV. Because mother's mental health problems and lower time investment are typically negatively associated with child development, these changes in maternal behaviour are likely to represent channels through which IPV affects child development.

VII Conclusions

The current paper has sought to estimate the impact of exposure to IPV on children's cognitive, social and socio-emotional skill development. We have adopted the approach of estimating production functions of child's skills on longitudinal data. Our analysis can therefore be related to both the existing literature in psychology on the damaging effects of children's exposure to abuse and, to the economics literature on human capital formation.

The overall question of the impact of IPV on children's outcomes is multi-dimensional: Are there critical stages of development when exposure to abuse is particularly harmful? At what age and for what outcomes do negative effects emerge? What forms of IPV are harmful to children's development? Does the skill development process allow children to recover from the damages caused by exposure to IPV? We would argue that the longitudinal nature of the data used for the above analysis and the econometric modelling applied provide a promising route towards answering at least some of the above questions.

We find that exposure to abuse early in life – between age zero to three – has negative effects on all three skills considered, but with differences in terms of the strength and in the timing of the emergence of these effects. We find the strongest and most immediate effects to be for socio-emotional skills. This finding is well in-line with the findings from the psychology literature (Latzman et al., 2019). In contrast, we find evidence of significant negative effects of IPV exposure during pre-school years on cognitive skills when of schooling age, a finding further verified in school-based skill measures (entry assessments and SATS tests). This suggests that children exposed to IPV early in life start school from an unfavourable position. Such initial disadvantage risks being amplified over time through dynamic complementarities.

variable is provided in the Appendix.

Table 6: Potential mechanisms - Mother's behaviour

	Panel A: Mother's mental health problems at t				
	(1)	(2)	(3)	(4)	(5)
Any past abuse	0.621***				
	(0.014)				
Any abuse (t)		0.798***	0.719***		
		(0.018)	(0.021)		
Any abuse (t-1)			0.329***		
			(0.023)		
Physical abuse (t)				0.708***	
				(0.036)	
Emotional abuse (t)					0.812***
					(0.019)
Observations	48,056	48,056	37,329	48,056	48056
	Panel B: Mother's time investment at t				
	(1)	(2)	(3)	(4)	(5)
Any past abuse	-0.007				
	(0.005)				
Any abuse (t)		-0.018***	-0.016***		
		(0.007)	(0.003)		
Any abuse (t-1)			-0.004		
			(0.003)		
Physical abuse (t)				-0.014	
				(0.013)	
Emotional abuse (t)					-0.015**
					(0.007)
Observations	50,912	50,912	40,599	50,912	50912

Notes: The dependent variable in Panel A is based on the Edinburgh Postnatal Depression Scale (EPDS) and is normalized on a period-by-period basis. The dependent variable in Panel B is a measure of time-investment in the child by the mother based on a set of activities. Details of each dependent variable are provided in the Appendix. The abuse variables indicate abuse reported by the mother either at the same time t or one period earlier $t-1$ as indicated. The regressions further include controls for the baseline characteristics in Table 1. Standard errors in parenthesis. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

While our findings point to the first three years of life as a critical period, we do not find any significant negative effects on skill accumulation of IPV exposure that occurs specifically after the child has started school. There can be several reasons for this, including simply the

fact that they spend more time outside the household and in the company of other people. It also likely reflects that exposure to IPV at this higher age in most cases will have been preceded by exposure during the pre-school years.[18]

Our analysis also did not uncover any negative skill effects of abuse reported by the mother while still pregnant.[19] This finding seems somewhat at odds with the recent findings (Aizer, 2011; Currie et al., 2018) that show negative effect of IPV during pregnancy on child health, notably birth-weight and APGAR scores. However, these findings relate to severe forms of IPV, leading either to hospitalization (Aizer, 2011) or a police report (Currie et al., 2018) for assault. The measure of IPV used in our analysis is, in contrast, much broader and more generally indicate intra-household hostility and conflict. This suggests that different forms of IPV are likely to have impacts on different dimensions of children's outcomes.

The current analysis also has several limitations, both relating to data and to modelling. In terms of data, ALSPAC is first and foremost a child development study. As such its strength lies in the measurements of children's outcomes. In contrast, the measurement of IPV is minimal: two annually repeated mother-reported answers to survey questions with possibly subjective interpretations. Nevertheless, the measures tally well with the best available data on IPV incidence in the UK, and importantly, it provides important insights into the dynamics of IPV around the critical time of child-birth.

On the modelling side, we have treated the various skills as separate processes. However, skills are likely to also interact. As argued by Cunha and Heckman (2007), socio-emotional skills foster cognitive skills as emotionally nurturing environments produce more capable learners. This can potentially account for why early exposure to IPV has an immediate effect on socio-emotional skills, but only a "delayed" effect on cognitive skills. Our analysis has also investigated some of the channels through which IPV exposure affect children's skill accumulation, i.e. divorce, mother's labour supply, mother's mental health and time investment. However, the richness of ALSPAC data provides opportunities for further analysis in this direction, by modelling jointly the interaction between various skill dimensions and parental inputs.

[18] We have not been able to estimate with any precision the effect of first IPV exposure when the child is of schooling age as first exposure at this advanced age is a low frequency event.

[19] It should be noted that we do find negative effects of abuse reported by the mother in the child's first year of life and that this includes abuse that may have occurred during the final trimester.

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Appendix: Details of Skill Measures and Maternal Inputs

Cognitive Skills

We use measures of cognitive skills from all periods $t = 2, ..., 7$. For the first three of these periods, $t = 2, 3, 4$, the measures used were based on the MacArthur Communicative Development Inventories (CDI) which are among the most widely used evaluation tools for early language development (Fenson et al., 2007). Cognitive skills at each age are modelled as a latent variable within a single-factor measurement model with the MacArthur component-scores as measurements. A latent factor model was estimated for each period using Stata SEM and the obtained latent cognitive skill variables were normalized period-by-period. At $t = 2$ (15 months) a three-component CDI was used involving one 134 words vocabulary inventory, 12 phrases, and 17 actions with objects. Each was summed to obtain a separate component-score. At $t = 3$ (24 months) a four-component CDI was used involving 123 words vocabulary inventory, 4 grammar questions, 5 plurals questions, and 20 past tens questions, each summed to obtain a component score. At $t = 4$ (39 months) a similar four-component CDI was used involving 123 words vocabulary inventory, 12 word combinations questions, 5 plurals questions, and 21 past tens questions, each summed to obtain a component score. The estimated factor loadings and signals are presented in Table A1, where the signal is the share of the variance of each measure that is explained by the latent factor. The strongest loadings – as measured by the signal-values – at $t = 2$ and $t = 3$ are on the vocabulary scores, while at $t = 4$ there the loadings on vocabulary and past tense scores are equally strong.

For periods $t = 5, 6, 7$, a shorter 15-question inventory, covering recognition of colours, letters and numbers was used. The summed score was normalized period-by-period and used as measure of cognitive skills.

Social Skills

We construct a measure of social skills in each period, $t = 1, ..., 7$. Our measures of social skills are based on the Denver Developmental Screening Test (DDST) which screens for age-specific milestones (Frankenburg and Dodds, 1967). The social milestones indicators evolve from how the child reacts to and interacts with family members and strangers to measures of playing, sharing, including showing empathy. These are combined with indicators of movement/physical development in relation to social activities, including eating, dressing, and helping out at home.

Table A1: Factor loadings - cognitive skills

	(1) Factor Loadings	(2) Signal
Panel A: MacArthur-Bates ($t = 2$)		
Vocabulary	1.000	0.709
Phrases	0.046	0.516
Actions/Objects	0.095	0.418
Panel B: MacArthur-Bates ($t = 3$)		
Vocabulary	1.000	0.851
Grammar	0.038	0.625
Plurals	0.040	0.668
Past Tense	0.188	0.702
Panel C: MacArthur-Bates ($t = 4$)		
Vocabulary	1.000	0.659
Plurals	0.075	0.624
Past Tense	0.347	0.666
Word Combinations	0.151	0.453

Notes: The table reports factor-loadings and signal-ratios from models relating latent cognitive skill to measurements. The measurements are based on MacArthur-Bates CDIs. Further details are provided in the text. The factor-loading for the first measurement in each panel represents a normalization.

The specific DDSTs involved: at $t = 1$ (6 months), a 10-milestones DDST of social skills along with movement/physical development; at $t = 2, 3, 4$ (18, 30 and 42 months), a 13-milestones DDST of social skills along with movement/physical development/eating, dressing; at $t = 5, 6, 7$ (57, 69 and 81 months), a 23-milestones DDST 23 of social skills along with movement/physical development/playing/sharing. The summed score was normalized period-by-period and used as measure of social skills.

Socio-emotional Skills

We use measures of socio-emotional skills from periods $t = 1, 3, 4, 7$. For the periods $t = 1, 3$, the measures used were based on the Carey Infant Temperament (CIT) questionnaire were temperament subscales are available to measure activity, rhythmicity, approach, adaptability, intensity, mood, persistence, and distractibility (Carey and McDevitt, 1977).

For the periods $t = 4, 7$, the measures used were based on the Strength and Difficulties Questionnaire (SDQ) using subscales indicating emotional symptoms, peer problems, conduct problems, hyperactivity and pro-social behaviour. Each subscale is reverse coded, so that posi-

tive values mean higher level of socio-emotional skills (Goodman, 1997).[20]

Table A2: Factor Loadings - Socio-emotional skills

	(1) Factor Loadings	(2) Signal
Panel A: CIT ($t = 1$)		
Adaptability	1.000	0.614
Approach	1.112	0.605
Mood	0.903	0.465
Rhytmicity	0.622	0.163
Persistence	0.494	0.189
Distractibility	0.841	0.448
Panel B: CIT ($t = 2$)		
Adaptability	1.000	0.699
Activity	0.692	0.282
Rhytmicity	0.468	0.080
Approach	0.541	0.060
Intensity	0.650	0.248
Mood	1.144	0.495
Persistence	0.570	0.165
Panel C: SDQ ($t = 4$)		
Prosocial Behaviour	1.000	0.117
Hyperactivity	1.633	0.313
Emotional sympthoms	1.083	0.138
Conduct Problems	2.037	0.487
Panel D: SDQ ($t = 7$)		
Prosocial Behaviour	1.000	0.287
Hyperactivity	1.158	0.385
Emotional sympthoms	0.738	0.156
Conduct Problems	1.350	0.523
Peer Problems	0.868	0.216

Notes: The table reports factor-loadings and signal-ratios from models relating latent socio-emotional skill to measurements. The measurements are based on the Carey Infant Temperament (CIT) at $t = 1, 3$ and on the Strength and Difficulties Questionnaire (SDQ) at $t = 4, 7$. Further details are provided in the text. The factor-loading for the first measurement in each panel represents a normalization.

Socio-emotional skills at each age are modelled as a latent variable within a single-factor measurement model with the CIT or SDQ scales as measures. A latent factor model was estimated for each period using Stata SEM and the obtained latent cognitive skill variables were normalized period-by-period. Table A2 reports the factor loadings (Column 1) and the signal, i.e. share of the variance explained by the latent factor for each measure (Column 2). The

[20]The pro-social behavior subscale, differently from all the other measures, does not need to be reversed to provide a consistent interpretation of higher scale higher socio-emotional skills.

variability in the signal across the different measures, highlight the importance of taking into account the measurement error with a latent factor model. We interpret the latent factor as a measure of socio-emotional skills for each period t.

School-Based Measures

As noted in the text, entry assessments (EAs) were used by and coordinated across the four Local Education Authorities (LEAs) that covered the former Avon area at the time when the ALSPAC study children entered school. The EAs taken the by ALSPAC children covered reading, writing, language and mathematics. Hence, each child is associated with four EA test scores, and we use these four scores as measurements reflecting their latent cognitive skills. A latent factor model was estimated using Stata SEM and the obtained latent cognitive skill variable was normalized.

A Key Stage (KS) is a stage of the state education system in England, Wales, Northern Ireland, and the National Curriculum sets out targets to be achieved in various subject areas at each of the Key Stages. KS1 comprises years 1 and 2, corresponding to ages 5-7. At the end of the KS1, students take Standard Assessment Tests (SATS) covering reading, writing and mathematics. Hence, each child is associated with three test scores, and we use these three scores as measurements reflecting their latent cognitive skills. A latent factor model was estimated using Stata SEM and the obtained latent cognitive skill variable was normalized.

The estimated factor loadings and signals are presented in Table . As expected, the signal-to-noise ratios are higher in the SATS when the children are older than in the entry assessments. The various components at each age generally have similar signal values.

Time investment

We use questions on mother's time investment for periods $t = 1...7$. The survey asks the mother to report how often she does the following activities with the child: (i) plays with the child; (ii) sings to child, (iii) shows child picture books; (iv) plays with toys together; (v) cuddles child; (vi) physically plays with child; (vi) takes child for walk; (vii) teaches child - with some questions changing over time to adapt to the child growing up. Similarly to what we have done for socio-emotional and cognitive skills, maternal time investment for every period t is modelled as a latent variable within a single-factor measurement model with each question asked to the mum as measure. We estimate a latent factor model for each period and then we normalize the factor period-by-period. Table A4 reports the factor loadings (Column 1) and the signal,

Table A3: Factor loadings - Entry Assessments and SATS

	(1) Factor Loadings	(2) Signal
Panel A: Entry Assessments ($t = 5$)		
Language	1.000	0.548
Reading	0.872	0.652
Writing	0.793	0.540
Word Combinations	0.986	0.539
Panel B: SATS ($t = 7$)		
Reading	1.000	0.818
Writing	0.824	0.813
Math	0.791	0.619

Notes: The table reports factor-loadings and signal-ratios from models relating latent cognitive skill to measurements. The measurements are based on school Entry Assessments and Key Stage 1 SATS. Further details are provided in the text. The factor-loading for the first measurement in each panel represents a normalization.

i.e. share of the variance explained by the latent factor for each question (Column 2) for period $t = 1$.[21] We interpret this factor as a measure of maternal time investment for each period t.

Mother's mental health

Mother mental health problems are measured with the Edinburgh Postnatal Depression Scale (EPDS), constructed on the basis of questions on mother's symptoms of depression and anxiety, typically characterizing the period after birth (Cox and Holden, 2003). The EPDS is designed to detect postnatal depression but also to provide information on factors that influence the emotional well-being of new mothers. The EPDS is available for periods $t = 1, 2, 3, 4, 6, 7$. We normalize the scale period-by-period to have zero mean and unit standard deviation.

[21] We follow the same procedure for periods $t = 2..7$. Factor loadings and signal are available upon request.

Table A4: Factor Loadings - Mother's time investment

	(1) Factor Loadings	(2) Signal
Time investment		
Mum plays with child	1.000	0.211
Mum sings to child	1.705	0.199
Mum shows child picture books	2.533	0.232
Mum and child play with toys	1.123	0.300
Mum cuddles child	0.202	0.060
Mum physically plays with child	1.301	0.242
Mum takes child for walks	1.111	0.102
Mum teach child	2.983	0.118

Notes: The table reports factor-loadings and signal-ratios from a models relating latent maternal investments to measurements. The measurements are indicators for specific activities. The table only reports estimates for $t = 1$. The same approach is used on all subsequent periods and the results are available on request. The loading on the first measurement represents a normalization. The estimated latent factor is normalized on a period-by-period basis and interpreted as a measure of maternal time-investments.