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The effect of prenatal stress on cooperation: Evidence from violent conflict in Uganda

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ABSTRACT

Are preferences endogenously determined in the womb? We play a public goods game with Ugandan children born during a conflict characterised by high civilian victimisation. Children whose caregivers suffer from post-traumatic stress disorder are more likely to free-ride in the game. Genetic and environmental factors alone do not explain the relationship, but children's 2D:4D digit ratio – a marker of fetal hormone exposure associated with epigenetic effects of maternal distress – does. Our findings extend the fetal origins literature to the domain of preferences. By reducing next generation's taste for cooperation, conflict may have father-reaching economic consequences than previously thought.

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1. Introduction

The nine months in utero may well be the most critical time in a person's life (Almond and Currie, 2011). Later-life characteristics are increasingly associated with “fetal origins”. Suffering from severe trauma and stress during pregnancy alters the hormone exposure of the child, triggering epigenetic processes that may shape brain evolution and behaviour (Dörner et al., 2001; Keverne and Curley, 2008). Among others, this was shown to affect future abilities, personality, and health trajectories. Do these in utero changes extend to the domain of social preferences?

We play a public goods game with 442 children born in Pader district in Northern Uganda during the 1998–2006 period of intense fighting between government forces and the Lord's Resistance Army (LRA). The game requires a one-shot dichotomous choice on whether to cooperate or not—free-riding being the only dominant strategy. Simultaneously we conduct an extensive socio-economic questionnaire including violent conflict exposure (victimisation), post-traumatic stress disorder (PTSD) symptoms, and a closely related public goods game with the child's main caregiver.

We find that children whose caregivers suffer from PTSD symptoms are significantly more likely to free-ride in the game. We speculate that this results from a combination of genetic and environmental intergenerational transmission mechanisms, but also epigenetic ones—through changes in hormone exposure during early fetal development. While it is impossible to measure the exact hormonal profile of fetuses later in life, we can proxy for it using a one of the many biometric markers of in utero hormone exposure, which develop mostly during early gestational stages and remain relatively stable throughout

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life. We opt for the 2D:4D digit ratio, which measures the relative length of the index finger with respect to the ring finger, and is therefore non-intrusive and relatively easy to measure (Lutchmaya et al., 2004; Manning et al., 2003; Zheng and Cohn, 2011). Like other biometric markers of prenatal hormonal exposure, the digit ratio is established through an epigenetic process in which hormones released by the mother's body modify the gene expressions of the fetus—rather than altering the genetic code itself. As such, it represents an interaction of nature – the child's genetic code – and nurture—the mother's hormonal reaction to environmental stimuli. In particular, the 2D:4D digit ratio is negatively related to the fetal testosterone-to-oestradiol (T:E2) ratio (Lutchmaya et al., 2004; Manning et al., 2003). Higher levels of maternal distress are associated with higher fetal testosterone levels (Ward and Weisz, 1980), higher fetal T:E2 ratios (vom Saal et al., 1990), and lower offspring 2D:4D digit ratios (Lilley et al., 2010). In fact, the children in our sample exhibit significantly lower digit ratios than their biological mothers and siblings born before the war. We also find that caregiver PTSD predicts lower digit ratios in children, but caregiver digit ratios do not predict caregiver traumatisation—suggesting that in our setting self-selection into trauma is not the main driver of this relationship. Under the assumption that violent conflict exposure and traumatisation were conditionally unconfounded in our context (Blattman, 2009; Blattman and Annan, 2010; Doom and Vlassenroot, 1999; Jackson, 2002), we therefore argue that the digit ratio may help us discern whether prenatal stress represents a third separate causal mechanism explaining the increased free-riding.

We show that prenatal stress does indeed affect preferences for cooperation: one standard deviation from the mean of our marker reduces the child's probability of contribution to the public good by around 7% points (i.e. –17% of the mean prevalence). We start with the observation that children of caregivers with PTSD symptoms are less likely to contribute to the public good. By showing that caregiver PTSD predicts lower 2D:4D digit ratio in their children, and that children born during conflict have lower digit ratios than their biological mothers and same-mother siblings, we confirm that the 2D:4D digit ratio is a reliable marker of prenatal stress. Together with caregiver preference for cooperation, it explains the entire effect of caregiver PTSD on child behaviour in the public goods game. To test whether this is a separate mechanism we introduce nature and nurture influences on the child, captured by the caregivers' choice in a closely related public goods game and in a simple risk game. As expected, caregiver cooperation significantly influences the child's independent decision to cooperate, while their risk preferences do not. Importantly, the effect of prenatal stress on cooperation remains robust and stable. We continue by showing that the relationship between prenatal stress and contribution to the public good is robust to controlling for other mechanisms through which conflict could influence cooperative preferences, including early life deprivation and direct conflict exposure. Finally, we account for self-selection into conflict exposure and trauma along observable characteristics through propensity score matching, and show that any unobserved factor would have to have an unrealistically large effect on cooperative behaviour in order to change our result.

We shed light on an alternative, epigenetic mechanism of preference transmission—beyond the standard nature-nurture debate. Preferences for cooperation may be endogenously determined right from the womb. If prenatal stress affects next generation's taste for cooperation, violent conflict may have farther reaching socio-economic consequences than previously thought. High incidence of severe prenatal stress may affect long-run development trajectories and post-conflict recovery across generations, even if the episodes of violence are limited in time.

The rest of the paper is organised as follows. Section 2 reviews the literature on the subject. Section 3 describes the context and background. Section 4 outlines the experimental design. Section 5 illustrates the empirical strategy and results, and Section 6 concludes.

2. Conflict, preferences, and prenatal stress

This paper explores the fetal origins of social preferences. It builds upon three strands of literature—that on the role of violent conflict in shaping preferences, that on the consequences of trauma in utero, and that on the relationship between prenatal hormone exposure and economic behaviour.

The relationship between violent conflict and the functioning of societies has been at the forefront of economic debate for years. War violence persistently impacts health, education, and poverty (Chamarbagwala and Morán, 2011; Gates et al., 2012; Ghobarah et al., 2003), but also affects individual preferences and behaviour. It has been found to increase community participation and political engagement (Bellows and Miguel, 2009; Blattman, 2009), out-group aggressiveness and competitiveness (Cecchi et al., 2016; Miguel et al., 2011), as well as risk propensity, and discount rates (Callen et al., 2014; Voors et al., 2011). Individuals exposed to inter-community violence display more altruistic behaviour, higher public good contributions, and trust within their networks (Gilligan et al., 2014; Voors et al., 2012). Intra-community violence instead decreases social cohesion and trust, and increases sentiments of group identity (Cassar et al., 2013; Rohner et al., 2013). Given the existing evidence of the transmission of preferences across generations (Dohmen et al., 2012), these changes may be expected to be passed on to the next generation both genetically (i.e. in case of survival bias) and through changes in nurture. Yet, especially for children conceived during or soon after severe violence, a third mechanism may be at play: that of epigenetic alterations caused by maternal stress while still in utero. To the best of our knowledge this is the first study attempting to gauge the effect of conflict-related stress on the social preferences of individuals that had yet to be born at the time that it first affected them.

Several studies have investigated the physical and psychological consequences of stress and traumatic events in utero. In fact, maternal prenatal anxiety may suppress the development of a functioning immune system, increasing the incidence of several health complications in infants (Stott, 1973). Moreover, exposure to violence during pregnancy has been found

to deteriorate birth outcomes, typically in terms of birth weight, fetal growth, and preterm delivery (Camacho, 2008; Koppensteiner and Manacorda, 2016; Lauderdale, 2006; Mancuso et al., 2004; Quintana-Domeque and Ródenas-Serrano, 2017).¹ Male fetuses tend to be more heavily affected than female ones (Black et al., 2016), and are generally less resistant to adverse conditions, as evidenced by higher rates of male fetal loss during periods of population stress (Catalano and Bruckner, 2006; Catalano et al., 2005a; 2005b; 2006; Fukuda et al., 1998; Hansen et al., 1999; Hernández-Julián et al., 2014; Quintana-Domeque and Ródenas-Serrano, 2017). Independent positive shocks, such as a rise in cocoa price at birth – expected to reduce financial distress in cocoa-producing areas of Ghana with respect to other regions – decrease the likelihood of mental distress during adulthood (Adhvaryu et al., 2015). Prenatal negative shocks, such as extreme weather or military invasions, are instead associated with higher prevalence of schizophrenia and autism (van Os and Selten, 1998; Walder et al., 2014).

In adults, the prolonged emotional disturbance and distress induced by conflict increases the likelihood of trauma, mental health problems, and PTSD (de Jong, 2002; Lopes Cardozo et al., 2004; Miller et al., 2008). The higher the post-traumatic hormonal release, the greater the chance that subjects develop PTSD (Delahanty et al., 2000). PTSD, in turn, increases the likelihood of persistent hormonal imbalance, particularly with respect to cortisol—the human stress hormone (de Kloet et al., 2008; Song et al., 2008; Steudte et al., 2011). During pregnancy, maternal stress is transmitted to the fetus through hormonal releases (Mancuso et al., 2004; Weinstock, 2008). Due to obvious ethical considerations, experimental studies of this mechanism are generally limited to laboratory rodents. Prenatally stressed rodents exhibit higher concentrations of serum testosterone and higher testosterone to oestradiol ratios (vom Saal et al., 1990; Ward and Weisz, 1980). In turn, the fetal testosterone to oestradiol ratio is negatively related to the 2D:4D digit ratio (Lutchmaya et al., 2004; Manning et al., 2003). Connecting the dots, Lilley et al. (2010) show that high levels of maternal corticosterone, the rodent equivalent to cortisol, are associated with lower offspring 2D:4D digit ratio. They suggest that the latter may be a useful phenotypic indicator of maternal distress during early fetal development.

The 2D:4D digit ratio measures the relative length of the index finger with respect to the ring finger. It is established through changes in gene expression which take place without a change in the DNA sequence – known as epigenetic modifications (Jirtle and Skinner, 2007) – and is widely accepted as a noninvasive marker and “lifelong signature of prenatal hormonal exposure” (Zheng and Cohn, 2011). During early fetal development, increased androgen hormones (e.g. testosterone) or the inactivation of the oestrogen receptor (ER- α) stimulate the ring finger growth, which leads to a lower 2D:4D ratio. On the other hand, the addition of oestrogen (e.g. oestradiol) or the inactivation of the androgen receptor (AR) decrease the ring finger growth, resulting in a higher 2D:4D ratio (Lutchmaya et al., 2004; Zheng and Cohn, 2011).

But why should prenatal hormonal changes affect later-life social preferences? On the one hand, the literature on violent conflict and preferences shows that economists increasingly agree that preferences are not hard-wired traits, but rather may change in response to shocks and life experiences. This literature however falls short of investigating if preferences can be shaped right from the womb. On the other, the “fetal origins” literature does investigate the relationship between prenatal hormones and later life cognitive and behavioural outcomes. Several studies have shown a correlation between the digit ratio and preferences. In the lab, Garbarino et al. (2010) show that a low 2D:4D is associated with greater risk-taking. This is confirmed by evidence that low digit ratio MBA students self-select more into risky finance careers (Sapienza et al., 2009), and that the financial ability among male high-frequency traders is negatively related to their 2D:4D ratio (Coates et al., 2009). Its relationship to social preferences is relatively less studied, especially on non-experimental populations. Among undergraduate students, Brañas-Garza et al. (2013) find a non-monotonic impact of the digit ratio on altruism, while others find a non-monotonic relationship between the digit ratio and cooperation in a prisoners' dilemma (Sanchez-Pages and Turiegano, 2010) and in a public goods game (Millett and Dewitte, 2006). Also, self-assessed low digit ratios (2D<4D) predict lower giving in ultimatum, trust, and public goods games (Buser, 2012).² We combine the literature about the epigenetic effects of maternal distress with that on the correlation between the digit ratio and preferences, bringing them to a natural experimental setting characterised by indiscriminate violence against unarmed civilians and high prevalence of maternal traumatisation. We use the 2D:4D digit ratio as a marker of maternal distress to explore how prenatal stress reflects on the preferences for cooperation of the next generation, trying to isolate its causal mechanism from other potential influences of direct and indirect violent conflict exposure.

¹ While the mechanisms through which maternal stress influences birth outcomes are still subject to intensive investigation, the leading hypotheses identify three channels: neuroendocrine, inflammatory/immune, and behavioural. See Hobel et al. (2008) and Dunkel Schetter (2011) for an overview of the biopsychosocial processes.

² Galizzi and Nieboer (2015) are the first to gather evidence of the link between the digit ratio and giving from a multi-ethnic sample. While confirming the findings of Brañas-Garza et al. (2013) for their Caucasian sample, they are not able to find any significant association for the other main ethnic groups. There are several reasons why we may be the first to find an effect of 2D:4D on social preferences for a non-Caucasian population. First, our sample is larger than that of Galizzi and Nieboer (2015): 442 instead of 26 “Black” observations (they also find no relationship for 221 “Chinese” and 81 “South Asians”). Second, our sample is more ethnically homogeneous: they consider constructs such as “Blacks” or “South Asians” as one great ethnicity and culture; in our sample the vast majority of people is ethnically “Acholi” – both genetically and culturally much less varied. This second point is particularly salient as literature (including Galizzi and Nieboer's study), show significant differences across ethnic groups when it comes to average digit ratios, which in turn may drive up standard errors. Third, different societies have significantly different preferences for altruism. A more genetically and culturally homogeneous group is therefore less likely to dilute the effect of the digit ratio.

Fig. 1. Civilian targeting in Pader district.

3. Context and background

In the last 25 years Uganda achieved high and steady GDP growth rates, averaging about 6.7% per year (World Bank, 2014). However, since independence in 1962, Uganda has witnessed many long periods of violence and constitutional suspension and only few short periods of peace and relative prosperity. In fact, even while the country's overall growth rate was faster than that of many of its neighbors by the end of the millennium, the North was enduring the last of a long series of conflicts: Joseph Kony's LRA insurgency (1987–2006).

Violence has been escalating recurrently in Uganda since 1971, when Idi Amin took power from the discredited President Milton Obote.³ Amin ruled the country until the 1979 Uganda–Tanzania War led to his ousting. Obote's comeback instead triggered the Ugandan Bush War against the southern rebels of the National Resistance Army (NRA) headed by the current President of Uganda, Yoweri Museveni. Obote lost power for the second time in 1985, shortly before the NRA faction assaulted Kampala—gaining the power it still holds today (Finnström, 2008).

As the balance of power shifted southwards, rebel movements in the North gathered under the flag of the LRA (Doom and Vlassenroot, 1999). Limited in numbers and resources, the LRA resorted to pillaging villages and abducting local youth: an estimated 60,000–80,000 people were abducted over two decades (Annan et al., 2006; Pham et al., 2007). Throughout the years, weak government responses and the setup of an Acholi self-defense militia invigorated the LRA, which scaled up operations to discipline the local population (Dolan, 2009; Finnström, 2008).⁴ The widespread killing and mutilation of Acholi civilians escalated dramatically after 1996, especially in the Acholi districts of Gulu, Kitgum, and Pader.⁵ In these districts, more than a quarter of the males aged 10–25 at the end of the war had been abducted for at least two weeks, and only 80% of them returned from captivity (Blattman and Annan, 2010).

Pader district was particularly hit from 1998 onwards, when LRA operations gained momentum and moved southwards (Fig. 1). Civilian fatalities peaked in 2002, after the start of “Operation Iron Fist” against rebel bases in South Sudan set off a bloody reaction by LRA forces. A truce between the LRA and the government was signed in 2006, and fighting in Uganda has been sporadic ever since.⁶

At its peak, LRA violence was largely indiscriminate and apparently random in nature. Small groups of roughly 15 fighters ventured into Uganda from their Sudanese bases for weeks at a time, ambushing government forces and raiding homesteads for supplies and recruits along the way. Homesteads, which tend to be relatively isolated in Northern Uganda, were targeted in an unplanned, arbitrary manner, regardless of their wealth or make-up (Blattman, 2009; Doom and Vlassenroot, 1999; Jackson, 2002). The randomness of the attacks was oftentimes deliberate, serving as a force multiplier to increase the

³ In 1966, Obote was implicated in a corruption scandal together with the then commander of armed forces, Idi Amin. He responded by suspending the constitution.

⁴ Civilian victimisation in these years was not only the result of LRA violence, and abuse from government troops was not uncommon.

⁵ Between 1994 and 2002, in response to Uganda's support for the rebels in South Sudan, the Sudanese government provided the LRA with logistic support and military equipment.

⁶ The LRA has not been disarmed nor demilitarised following the 2006 truce with the Ugandan government, and has been active in the Democratic Republic of the Congo, the Central African Republic and South Sudan.

Fig. 2. Average traumatisation per school.

perception of undiscerning threat in the civilian population (Vinci, 2005). Fig. 2 shows the relative level of traumatisation (PTSD), corresponding with the diameters of the circles representing each school in our sample. Coherent with literature, we find that traumatisation shows no detectable spatial autocorrelation on the school level (Moran's $I = -0.030$), nor are they correlated within schools (intra-class correlation coefficient is $\rho = 0.020$).⁷ We come back to the plausibility of selection bias and the sensitivity of our results to the unconfoundedness assumption in Section 5.5.

4. Experimental design

Employing new data from behavioural games, biometric measurements and an extensive socioeconomic survey, we exploit the quasi-experimental variation in war exposure generated by rebel raids in Northern Uganda villages to gauge the impact of prenatal stress on later-life cooperation.

4.1. Sample and setting

Our sample includes 442 children and their caregivers from Pader district in Northern Uganda. In November 2012 we visited 42 primary schools in the district, and randomly selected 12 students from a list of pupils enlisted at the beginning of the year.⁸ The descriptive statistics for the children are presented in Table 1. The average digit ratio – our marker of prenatal stress – is 0.94 in our sample, and 41% of the children chose to cooperate in the public goods game. Sections 4.2 and 4.3 below discuss the details of the digit ratio measurement and of the public goods game set-up respectively. On average the children are 11 years old, half of them are female, and their body mass and height are, respectively, 0.4 and 1 standard deviation below the mean for their age (de Onis et al., 2007).⁹ To control for additional potential confounds, we also collect information about the children's cognitive ability (IQ) through standard Raven's progressive matrices (Kaplan and Saccuzzo,

⁷ See Fig. B.1 for a graphic representation of the distribution of war exposure instead. See Tables A.1 and A.2 for full results of spatial autocorrelation and intra-class correlation analysis, respectively, for both war exposure and traumatisation.

⁸ The randomisation was stratified according to grade: 4 students were selected from grade 2, 4 from grade 4, and 4 from grade 6. Out of a total of 504, 62 students born prior to the intensification of violence in the area around 1998 were excluded from the analysis.

⁹ Based on WHO recommendations for treating outliers (de Onis et al., 2007), we truncate the biometric data at 6 standard deviations from the mean. This results in 1 and 2 dropped observations for height-for-age and BMI-for-age, respectively.

Table 1
Descriptive statistics (children).

Variable	Mean	Std. dev.	Min.	Max.	Observations
2D:4D	0.943	0.042	0.733	1.111	442
Public good contribution	0.414	0.493	0	1	442
Age	11.045	2.160	6	14	442
Female	0.500	0.501	0	1	442
School grade	3.575	1.494	2	6	442
Height-for-age	−0.428	1.381	−4.82	5.80	441
BMI-for-age	−1.034	1.088	−5.98	2.01	440
IQ-for-age	95.59	15.00	79.92	162.73	442
Time preferences	0.253	0.435	0	1	442
Risk preferences	0.403	0.491	0	1	442
War exposure	0.537	0.249	0	0.958	440

Note: See [Appendix C](#) for variable definitions.

Table 2
Descriptive statistics (caregivers).

Variable	Mean	Std. dev.	Min.	Max.	Observations
2D:4D	0.957	0.038	0.844	1.066	154
Public good contribution	0.507	0.501	0	1	442
Age	42.03	11.87	19	92	440
Female	0.534	0.499	0	1	442
Caregiving time	0.905	0.193	0.038	1	438
Education level	0.839	0.802	0	4	442
Risk preferences	0.312	0.464	0	1	442
War exposure	0.752	0.166	0.174	1	440
PTSD (dummy)	0.391	0.489	0	1	442
PTSD (factor)	0.000	1.000	−1.926	2.339	442
Christian	0.991	0.095	0	1	442
Acholi	0.973	0.163	0	1	442
Household size	8.093	2.988	2	25	442
Asset index	0.000	1.000	−0.571	5.507	442

Note: See [Appendix C](#) for variable definitions.

2012), as well as their time and risk preferences (Voors et al., 2012). Child postnatal war exposure is a composite measure derived from the exposure of the caregiver and the child's year of birth (see [Section 4.4](#)).

To account for environmental and genetic effects on preferences, we also interviewed each child's main caregiver—the adult household member with whom the child spends most time. The descriptive statistics for the caregivers are presented in [Table 2](#). About half of the caregivers in our sample chose to cooperate in the public goods game (see [Section 4.3](#) for details about the public goods game). Caregivers are on average 42 years of age,¹⁰ 53% are female, and they were the child's primary caregiver for 91% of the child's life. Additionally, we collected information about their education level and risk preferences. All caregivers were exposed to at least some kind of conflict-related violence (thought the level of exposure varies greatly in our sample),¹¹ and 40% suffer from PTSD symptoms. The details of war exposure and trauma measurements are discussed in [Section 4.4](#) below. Almost the entire sample is ethnically Acholi and Christian by religion. Households are typically composed of 8 people. We also collected information about their relative asset wealth ([Sahn and Stifel, 2003](#)).

In our setting, information about the current main caregivers can only serve as a proxy for environmental and genetic influences to which the children have been subjected throughout their lives. Of the 442 caregivers in our sample, only 190 are biological mothers. Another 163 are biological fathers, while the remaining 87 were grandparents, uncles/aunts, siblings or other relatives (in descending order of prevalence). 2 caregivers were not blood-related to the child at all. Nonetheless, the average caregiver in our sample had been taking care of the child for 93% of the child's life, making the information about the caregivers a strong proxy for the environment surrounding the children.

4.2. The digit ratio

The index and ring finger lengths were measured on the ventral surface of the right hand from the midpoint of the basal crease to the tip of the digit. Given the contextual constraints and instruments available, measurement precision does not exceed 1 mm, resulting in an error of $\pm 3.3\%$ at the mean of our estimations.¹² While this is still far from the precision

¹⁰ Two caregivers did not know their age, reducing the number of observations to 440.

¹¹ Two caregivers refused to complete the war exposure module of the survey, reducing the number of observations to 440. This reduction carries over to the measure of child postnatal war exposure, which is derived from that of their caregiver.

¹² In a pilot, 30 raters separately measured 35 right hands, revealing comparable margins.

obtained in the lab (see Voracek et al., 2007), independent raters measured the digit lengths unaware of their scientific significance; errors should therefore result in unbiased random noise.¹³

4.3. Public goods game

We measure children's and caregivers' willingness to cooperate by involving them in a one-shot dichotomous public goods game similar to Cárdenas et al. (2009) and Barr et al. (2014). In each school, children played in randomly assigned groups of 6, and anonymously decided whether to select a "private card" or a "group card".¹⁴ Children could in no way infer which other 5 participants belonged to their group (out of the 11 other children selected in that school), which afforded them plausible deniability. The private card allotted 3 candies to themselves and none to other unknown group members. The group card gave instead 1 candy to each group member including themselves (a graphical representation of the two cards can be found in Fig. B.2). The joint surplus is therefore maximised when all participants choose the group card, such that each group member receives 6 candies. Nevertheless, free riders selecting the private card may obtain up to 8 candies. The Nash equilibrium is reached if everyone selects the private card, receiving 3 candies only. Caregivers played a very similar game, but played in groups of 12 instead of 6. The game was played in an isolated environment – typically their home – and caregivers were unaware of the identity of other participants. The private card was worth 4000 UGX (roughly the average daily income of a household head in Northern Uganda), equivalent to approximately 1.5 USD; the group card was instead worth 500 UGX. The non-cooperative equilibrium thus yielded 4000 UGX each, joint maximisation returned 6000 UGX each, and free riders could earn as much as 9500 UGX.¹⁵ On average, 41% of the children and 51% of the caregivers opted for the cooperative option offered by the group card.

4.4. War exposure and trauma

Given their young age at the time of the conflict, we do not ask children war-related questions. Instead, we use information on the individual war exposure of their caregivers, and weigh it against the war violence that happened after the year of birth of the child. We use an adapted version of the War Trauma Questionnaire (WTQ), excluding the questions about shelling and bombardment which are not relevant to our setting (Macksoud, 1992; Papageorgiou et al., 2000). This questionnaire provides information on 23 war related traumatic events that a person may have witnessed, rated through "yes" or "no" statements.¹⁶ We create a war exposure (victimisation) index using the average of positive responses to these violence related questions (Bellows and Miguel, 2009). On average, caregivers responded positively to 75% of the questions, with a minimum observed exposure of 17%. To proxy the child's postnatal war exposure we weight the caregiver's war exposure index by the portion of violence potentially witnessed by the child after birth. To this end, we take the fraction of total civilian fatalities that occurred in Pader district following the child's birth (see Fig. 1).¹⁷

We measure caregiver PTSD symptoms using the civilian version of the PCL self-report checklist (Weathers et al., 1993).¹⁸ We convert individual scores into a PTSD dummy, following the recommendations of the US Department of Veteran Affairs,

¹³ Approximately two years after the main data collection we re-measured the digit lengths for a non-random sub-sample of 258 respondents. While the absolute length of the fingers had undoubtedly changed in the meanwhile, their ratio should remain relatively stable throughout lifetime. In line with expectations, the average error was $\pm 3.7\%$. Although the measurement and re-measurement are somewhat weakly correlated, our results are not driven by systematic measurement error, and excluding measures with potentially greater error does not significantly alter the results (see Table A.3).

¹⁴ Contrarily to many public goods games in which participants can choose their preferred contribution level, we opted for a dichotomous choice: respondents could either cooperate or not. While this reduced our ability to pick up the nuances present in the experimental sample, we believe that it facilitated the decision making process, especially for the youngest.

¹⁵ Besides the currency (Ugandan Shillings instead of candy), the game played by the caregivers differs from that played by the children in several aspects: For logistical reasons, the caregivers were interviewed in their homes, whereas the children were interviewed in schools. Unlike their caregivers, the children therefore knew who else was being interviewed. In order to afford them the same plausible deniability as their caregivers enjoyed, we split the children into two game groups of 6 instead of one group of 12 in each school. The children knew this, but did not know which 5 of the other 11 interviewed children played with them. The different locations also necessitated different payout mechanisms. The children were paid in their schools where a research assistant was always present. The caregivers could only be paid once the decisions of their peers were collected in a central location (the school). The research assistants who interviewed them therefore had to leave the interview location before a payment could be made. Finally, we adjusted the relative values of the "private" and "group" cards during a pilot in order to maximise the variance of the responses in both samples and thus facilitate parametric analysis. Specifically, the number of candies assigned by the "private" card in the child version was dropped from 4 to 3 to increase the likelihood that children would select the "group" card.

¹⁶ We opted for the WTQ because it is standardized and well tested. The downside of this choice is that it lacks information on when the traumatic events took place. While this is an important limitation, it does not directly affect our identification strategy, which relies on the digit ratio.

¹⁷ Source: ACLED Version 6.

¹⁸ The civilian version of the PCL self-report checklist – a 17-item questionnaire – has been found to have strong psychometric properties, high internal consistency, and high test-retest reliability (Blanchard et al., 1996; Conybeare et al., 2012; Ruggiero et al., 2006). Moreover, it is strongly correlated with alternative measures of PTSD such as the Mississippi, MMPI-2 Keane, IES, and CAPS scales (Dobie et al., 2002; Freedy et al., 2010; Weathers et al., 1993).

Table 3

Caregiver PTSD predicts lower child cooperation.

	Public good contribution				
	(1)	(2)	(3)	(4)	(5)
Caregiver PTSD	−0.072** (0.035)	−0.070** (0.033)	−0.086** (0.036)	−0.089** (0.036)	−0.087** (0.038)
Child controls	N	Y	Y	Y	Y
Caregiver and peer controls	N	N	Y	Y	Y
Sub-county fixed effects	N	N	N	Y	Y
Child risk and time preferences	N	N	N	N	Y
Household size and assets index	N	N	N	N	Y
Observations	442	442	436	436	436
R ²	0.005	0.011	0.043	0.047	0.049

Notes: Standard errors corrected for school level clustering (42) are in parentheses. Confidence: *** $\leftrightarrow$ 99%, ** $\leftrightarrow$ 95%, * $\leftrightarrow$ 90%. Child controls: Age, Female, Age $\times$ Female; Caregiver controls: Age, Female, Age $\times$ Female, Caregiving time, Acholi, Education; Peer controls: Proportion of excluded peers, Class dummies. See Table A.8 for the full list of coefficients.

and the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM4).¹⁹ As an additional robustness check, we perform factor analysis to extrapolate a factor for trauma.

5. Analysis and results

5.1. Caregiver PTSD and child cooperation

We first test whether caregiver PTSD significantly changes the child's likelihood to free-ride in our public goods game. Table 3 presents results of a linear probability estimation (unless otherwise stated, all estimations below are also of linear probability models) showing that children whose caregivers suffer from PTSD symptoms are up to 9% points less likely to contribute to the public good (i.e. −22% of the mean prevalence). The result is robust to controlling for sub-county fixed effects, child and caregiver characteristics, household size and asset index, as well as child risk and time preferences (columns 1–5).

Result 1. Children whose caregivers suffer from PTSD symptoms are robustly less likely to contribute to the public good.

5.2. Prenatal stress and child digit ratio

While this result is interesting in itself, it does not say much about the mechanisms through which traumatised caregivers may transmit a preference for lower cooperation to the child. The literature on the intergenerational transmission of preferences predicts that caregivers transmit their own preferences both genetically (i.e. directly transmitting their own hard-wired preference set) and through environmental influences (i.e. more or less voluntarily “teaching” the child to free-ride or cooperate). We hypothesise that a third mechanism may be at play: the epigenetic effect of prenatal stress. To proxy for this, we introduce a standardised measure of the 2D:4D digit ratio—an indicator of maternal distress during early fetal development. As digit ratios are expected to become smaller in response to increased maternal distress during early fetal development (i.e. increased fetal testosterone to oestradiol ratios), we use the negative standardised digit ratio as relative measure of prenatal stress:

$$\text{DigitRatio}_{is} = -\frac{2D : 4D_{is} - \overline{2D : 4D}}{\sigma} \quad (1)$$

where $2D : 4D_{is}$ is the digit ratio of individual i ; $\overline{2D : 4D}$ is the mean digit ratio in the sample; σ is the standard deviation; and the negative sign produces a positive relationship between our proxy and actual prenatal stress—for ease of interpretation.

Yet, for our marker of prenatal stress to plausibly explain part of the relationship we observe in Table 3, we need to find evidence in our data that it is affected by victimisation during the conflict. Through a series of paired t -tests we compare the digit ratio of (84) biological mothers to that of their offspring (Table 4, row 1), and of their female offspring only (43) (Table 4, row 2). Moreover, we identify same-mother siblings born between 1990 and 1996, a relatively non-violent

¹⁹ In our setting, we expect high rates of PTSD (Pfeiffer and Elbert, 2011; Roberts et al., 2008). We therefore take a conservatively high threshold for PTSD, at >66% of the maximum item score, to minimise the likelihood of false positives (Keen et al., 2008). We therefore find a lower PTSD prevalence (40%) than previous studies in the region that do not apply this correction. The DSM4 cut-off point requires at least 1 moderately positive answer in questions 1–5, 3 in 6–12, and 2 in 13–17. At the selected threshold, only 4 out of 442 caregivers do not meet this requirement. Our analysis is robust to their inclusion or exclusion from the PTSD count.

Table 4

Children born during the conflict exhibit lower digit ratios than their relatives.

	Observations		2D:4D		
	Child	Control	Child	Cont.	Diff.
Biological mothers	84	84	0.942	0.956	−0.013*** (0.005)
Biological mothers (female child)	43	43	0.940	0.953	−0.013** (0.006)
Same-mother sibling	43	43	0.936	0.948	−0.013* (0.008)
Same-mother sibling (same sex)	26	26	0.941	0.950	−0.009 (0.008)

Notes: Confidence: *** ↔ 99%, ** ↔ 95%, * ↔ 90%.

Table 5

Caregiver trauma predicts lower digit ratio in children.

	Standardised digit ratio			
	(1)	(2)	(3)	(4)
PTSD	−0.296** (0.111)	−0.290** (0.130)		
Trauma factor			−0.116** (0.051)	−0.109* (0.061)
Child controls	N	Y	N	Y
Caregiver controls	N	Y	N	Y
Sub-county fixed effects	N	Y	N	Y
Observations	442	436	442	436
R ²	0.021	0.050	0.013	0.042

Notes: Standard errors corrected for school level clustering (42) are in parentheses. Confidence: *** ↔ 99%, ** ↔ 95%, * ↔ 90%. Child controls: Age, Female, Age × Female; Caregiver controls: Age, Female, Age × Female, Caregiving time, Acholi, Education.

period in Pader district. We test the hypothesis that (43) siblings born prior to the intensification of war violence have a significantly different digit ratio (Table 4, row 3), and verify its robustness by looking at (26) same-sex siblings (Table 4, row 4).²⁰ Children born during the conflict have significantly smaller digit ratios than their relatives born before the conflict.²¹

This result is in line with previous evidence that prenatal stress results in smaller digit ratios (Lilley et al., 2010; vom Saal et al., 1990; Ward and Weisz, 1980). In particular, we observe a reduction in the digit ratio of approximately 1/4 of a standard deviation. Next, we test whether PTSD of the caregiver actually predicts lower digit ratio in children using the following model:

$$2D : 4D_{is} = \alpha + \beta \text{CaregiverPTSD}_{is} + \gamma' \mathbf{X}_{is} + \zeta_s + \varepsilon_{is} \quad (2)$$

where $\text{CaregiverPTSD}_{is}$ is a measure of the PTSD symptoms of the caregiver, $\mathbf{X}_{is}$ is a vector of child characteristics including age, gender, and their interaction, and caregiver characteristics including age, gender, their interaction, ethnicity and education. ζ_s represents sub-county fixed effects, and ε_{is} is a stochastic error term.

Table 5 shows that PTSD in caregivers is associated with child 2D:4D digit ratios that are lower by approximately 0.3 of a standard deviation (columns 1 and 2). As a robustness check, columns 3 and 4 show instead a traumatisation factor derived from the same PTSD questions: one standard deviation increase in traumatisation results in a lower digit ratio by about 0.1 standard deviations (columns 3 and 4).

Result 2. Children born during the conflict exhibit significantly lower digit ratios than their biological mothers and same-mother siblings. Also, caregiver trauma predicts lower digit ratios in children.

We then proceed to test whether genetic, environmental, and epigenetic mechanisms explain away the relationship of Table 3. We first introduce as additional explanatory variable the caregiver's choice in the public goods game to capture the effects of nature and nurture (columns 1 and 2), and later our marker of prenatal stress (columns 3 and 4). Columns 1 and 2 of Table 6, show that while the coefficient of PTSD is lower, it is still significant. Columns 3 and 4 of Table 6 show that once

²⁰ The difference between the 2D:4D ratio of mothers and that of their children (row 1) could be expected as half the children are male, who typically exhibit lower 2D:4D than females. However, the digit ratios of mothers and their daughters differ in a similar way (row 2), suggesting that the difference is not due only to sexual dimorphism. Similarly, the difference between the digit ratios of same-mother siblings could be due to sexual dimorphism in such a small sample, but the difference between same-mother siblings of the same sex cannot be.

²¹ This involved a separate step of data collection: in 2014 we traced back as many mothers and older siblings of the sampled children as possible given the time gap, and measured their digit ratios.

Table 6
Caregiver cooperation and prenatal stress explain the effect of PTSD on child cooperation

	Public Good Contribution			
	(1)	(2)	(3)	(4)
Standardized digit ratio (–)			–0.069** (0.026)	–0.070*** (0.026)
Caregiver public good contribution	0.150*** (0.040)	0.150*** (0.045)	0.141*** (0.042)	0.139*** (0.047)
PTSD	–0.056 (0.035)	–0.076** (0.036)	–0.036 (0.038)	–0.057 (0.038)
Child controls	N	Y	N	Y
Caregiver and peer controls	N	Y	N	Y
Sub-county fixed effects	N	Y	N	Y
Observations	442	436	442	436
R ²	0.028	0.0369	0.047	0.088

Notes: Standard errors corrected for school level clustering (42) are in parentheses. Confidence: *** $\leftrightarrow$ 99%, ** $\leftrightarrow$ 95%, * $\leftrightarrow$ 90%. Child controls: Age, Female, Age $\times$ Female; Caregiver controls: Age, Female, Age $\times$ Female, Caregiving time, Acholi, Education; Peer controls: Proportion of excluded peers, Class dummies. See Table A.8 for the full list of coefficients.

Fig. 3. Digit ratio quartiles and prevalence of public good contributions.

the 2D:4D digit ratio is introduced, the direct effect is further reduced and becomes insignificant. Moreover the adjusted R^2 actually increases once PTSD is removed from the model.

5.3. Child digit ratio and public good contribution

Having established a negative relationship between caregiver PTSD and child digit ratio, we continue by analyzing the relationship between children's digit ratios and their cooperation in the public goods game graphically. From Buser (2012) we expect it to be negative. Indeed, Fig. 3 illustrates that the prevalence of public good contributions decreases among children with lower digit ratio—as prenatal stress increases.

Parametrically, we show this relationship by estimating a specification with only the prenatal stress proxy as a regressor:

$$Cooperation_{is} = \alpha + \beta DigitRatio_{is} + \varepsilon_{is} \quad (3)$$

where $Cooperation_i$ is a dummy taking value of 1 if individual i played the group card in the public goods game; $DigitRatio_{is}$ is our measure of prenatal stress. Standard errors are clustered for 42 schools.

Table 7
Prenatal stress reduces cooperation.

	Public good contribution					
	(1)	(2)	(3)	(4)	(5)	(6)
Standardized digit ratio (–)	–0.078*** (0.024)	–0.072*** (0.025)	–0.070*** (0.025)	–0.073*** (0.025)	–0.073*** (0.025)	–0.074*** (0.025)
Caregiver public good contribution		0.144*** (0.041)	0.141*** (0.041)	0.144*** (0.046)	0.143*** (0.048)	0.143*** (0.047)
Caregiver risk averse		0.001 (0.054)	–0.002 (0.055)	0.007 (0.058)	0.009 (0.056)	0.008 (0.056)
Child controls	N	N	Y	Y	Y	Y
Caregiver and peer controls	N	N	N	Y	Y	Y
Sub-county fixed effects	N	N	N	N	Y	Y
Child risk and time preferences	N	N	N	N	N	Y
Household size and assets index	N	N	N	N	N	Y
Observations	442	442	442	436	436	436
R ²	0.025	0.046	0.050	0.082	0.085	0.088

Notes: Standard errors corrected for school level clustering (42) are in parentheses. Confidence: *** $\leftrightarrow$ 99%, ** $\leftrightarrow$ 95%, * $\leftrightarrow$ 90%. Child controls: Age, Female, Age $\times$ Female; Caregiver controls: Age, Female, Age $\times$ Female, Acholi, Education; Peer controls: Proportion of excluded peers, Class dummies. See Table A.8 for the full list of coefficients.

Table 8
The effects of prenatal stress on cooperation are heterogeneous by age and gender.

	Public good contribution			
	(1)	(2)	(3)	(4)
Standardized digit ratio (–)	–0.123*** (0.034)	–0.124*** (0.038)	–0.039 (0.131)	0.014 (0.137)
Female	0.002 (0.048)	–0.234 (0.254)		
Female $\times$ Standardized digit ratio (–)	0.093** (0.044)	0.102** (0.049)		
Age			0.014 (0.011)	0.015 (0.020)
Age $\times$ Standardized digit ratio (–)			–0.003 (0.011)	–0.008 (0.012)
Child controls	N	Y	N	Y
Caregiver and peer controls	N	Y	N	Y
Sub-county fixed effects	N	Y	N	Y
Observations	442	436	442	436
R ²	0.034	0.095	0.029	0.086

Notes: Standard errors corrected for school level clustering (42) are in parentheses. Confidence: *** $\leftrightarrow$ 99%, ** $\leftrightarrow$ 95%, * $\leftrightarrow$ 90%. Child controls: Age, Female, Age $\times$ Female; Caregiver controls: Age, Female, Age $\times$ Female, Caregiving time, Acholi, Education; Peer controls: Proportion of excluded peers, Class dummies.

We find that our marker of prenatal distress is negatively correlated with the child's probability of contribution to the public good (Table 7, column 1).²² Yet, this relationship could potentially be driven by other child characteristics. First, of course, the preferences of children may be driven by those of their caregivers through environmental as well as genetic mechanisms (Dohmen et al., 2012). We find a strong relationship between the social preferences of the caregiver and the child, but not between the risk preferences of the caregiver and the social preferences of the child. Children are about 15% points more likely to contribute if their main caregiver contributes to the public good in a separate game.²³ Second, prosocial preferences develop throughout childhood and adolescence, and become increasingly gender-dependent with approaching adulthood (Eisenberg et al., 2006). Controlling for age, gender, their interaction, for school grade and for tribe does not, however, alter the result (see Table 7, column 3). Third, the probability of contributing to the public good may also be influenced by the social environment in which a child is growing up. Both family and peer demographics have been linked to children's prosocial behaviour, though the evidence is often inconclusive (Eisenberg et al., 2006). To account for possible environmental influences, we control for caregiver characteristics including the level of education, gender, age, and the interaction of the latter two. We also control for the proportion of children who participated in the public goods game,

²² Previous research suggests that the relationship between the digit ratio and cooperation may be non-monotonic (Millet and Dewitte, 2006; Sanchez-Pages and Turiegano, 2010). Testing for non-linear effects by including a quadratic digit ratio term in the estimation (see Table A.4), we find that our result is strictly linear.

²³ For a sub-sample of 154 parents, we verify that the parents' digit ratio is not driving our result—i.e. the genetic component does not foreshadow the epigenetic effect. We find no effect of parental digit ratios on the cooperation of children (see Table A.5).

Table 9

Alternative mechanisms: postnatal war exposure and early life deprivation.

	Public good contribution				
	(1)	(2)	(3)	(4)	(5)
Standardized digit ratio (–)	–0.076*** (0.024)	–0.079*** (0.025)	–0.077*** (0.025)	–0.076*** (0.026)	–0.075*** (0.026)
Postnatal war exposure	0.024 (0.021)	–0.007 (0.030)			0.005 (0.031)
Height-for-age			0.025* (0.015)	0.058*** (0.020)	0.057*** (0.020)
BMI-for-age			–0.015 (0.025)	–0.018 (0.023)	–0.018 (0.024)
IQ-for-age			–0.012 (0.021)	–0.014 (0.025)	–0.012 (0.026)
Child controls	N	Y	N	Y	Y
Caregiver and peer controls	N	Y	N	Y	Y
Sub-county fixed effects	N	Y	N	Y	Y
Observations	440	434	440	434	432
R ²	0.027	0.066	0.030	0.082	0.083

Notes: Standard errors corrected for school level clustering (42) are in parentheses. Confidence: *** $\leftrightarrow$ 99%, ** $\leftrightarrow$ 95%, * $\leftrightarrow$ 90%. Child controls: Age, Female, Age $\times$ Female; Caregiver controls: Age, Female, Age $\times$ Female, Caregiving time, Acholi, Education; Peer controls: Proportion of excluded peers, Class dummies.

but were excluded from the analysis due to their age (column 4).²⁴ The inclusion of these additional covariates does not affect the main result (see Table 7, column 3), nor does the inclusion of spatial fixed effects (see Table 7, column 5). We also control for family size and wealth, both of which have been associated with children's prosocial preferences (Zaff et al., 2003), as well as for the child's risk and time preferences, to reach the following fully specified linear probability model in column 6:²⁵

$$\text{Cooperation}_{is} = \alpha + \beta \text{DigitRatio}_{is} + \gamma' \mathbf{X}_{is} + \delta_s + \zeta_s + \eta' \mathbf{Z}_{is} + \varepsilon_{is} \quad (4)$$

where Cooperation_{is} is a dummy taking value of 1 if individual i played the group card in the public goods game; DigitRatio_{is} is our measure of prenatal stress; $\mathbf{X}_{is}$ is a vector of child characteristics including age, gender, age $\times$ gender, education, ethnicity, and caregiver characteristics including age, gender, age $\times$ gender and education; δ_s represents the fraction of children in a school excluded from our analysis; ζ_s the spatial fixed effects at the sub-county level; and $\mathbf{Z}_{is}$ a vector of covariates including household size, assets, time preferences and risk preferences of child i . Standard errors are still clustered for 42 schools.

The additional covariates included in vector $\mathbf{Z}_{is}$ are potentially endogenous to our model. Since, they do not alter the main result (see Table 7, column 6), nor is their correlation with the probability to contribute to the public good statistically significant (see Table A.8), we exclude them from any further analysis.

Throughout several specifications – controlling for an increasingly extensive set of covariates – the main result remains stable: One standard deviation drop in the digit ratio decreases the child's probability of contribution to the public good by around 7% points, or around 17% of the mean prevalence.

We further explore this result by analyzing the heterogeneity of prenatal stress effects on cooperation along the observed child characteristics, i.e. gender and age. As can be seen from columns 1 and 2 in Table 8, the effects of prenatal stress on cooperation are strongly dependent on gender—prenatal stress reduces cooperation in boys, but not in girls. This is more apparent in Fig. 4, which plots the marginal effects and their 95% confidence intervals calculated from both the direct and the interaction terms following Berry et al. (2012). A stronger effect on boys is in line with previous studies which find male fetuses to be more sensitive to condition in utero than female ones (see e.g. Black et al., 2016; Catalano and Bruckner, 2006; Quintana-Domeque and Ródenas-Serrano, 2017.) Fig. 4 also shows that the effects of prenatal stress on cooperation become stronger (and statistically significant) in older children, which is not readily apparent from columns 3 and 4 in Table 8. This is also not entirely surprising as prosocial preferences develop (and become increasingly gender-dependent) with a child's increasing age (Eisenberg et al., 2006). Importantly, it assuages the concern the effect at play may be transient and dissipate in time.

²⁴ We initially sampled 4 second-graders, 4 fourth-graders and 4 sixth-graders from each of the 42 schools, resulting in a total sample of 504 children. All 12 children from each school would participate in the public goods game, but only those born after the re-escalation of violence in Pader district in 1998 were included in our analysis, resulting in a removal of between 0 and 5 children per school. Since prosocial preferences increase with age, younger children playing the game in a group with a high share of older children may be more likely to contribute to the public good due to both peer effects and rational expectations about the behaviour of the older children.

²⁵ In our main specification, the predicted probabilities lie between 0.003 and 0.815; we thus expect our estimations to be largely unbiased and consistent. In fact, marginal effects calculated through a probit very closely resemble those of our selected linear probability model (see Table A.6, column 1). See Horrace and Oaxaca (2006) for a detailed discussion of the trade-offs between linear probability and binary classification models.

Fig. 4. The effects of prenatal stress on cooperation are heterogeneous by age and gender.

Result 3. Prenatal stress reduces the taste for cooperation. One standard deviation drop in the digit ratio decreases the child's probability of contribution to the public good by 17%. The effects are exclusive to boys, and become more prominent in older children.

5.4. Alternative mechanisms

Next, we investigate potential alternative mechanisms. First, [Section 2](#) highlights the role of postnatal war exposure in shaping individual preferences. The children in our sample were at most 8 years of age at the end of hostilities, but postnatal witnessing of conflict-related violence may still have affected their taste for cooperation ([Bauer et al., 2014](#)). Second, the literature discussed in [Section 2](#) predicts that prenatal stress may capture the effect of early life deprivation. Height, for instance, is an anthropometric indicator of early-life experiences comparable to longitudinal measures such as height and weight at birth ([Currie and Vogl, 2013](#)). Similarly, low birth weight is associated with later-life low BMI ([Walker et al., 2002](#)), and severe deprivation at an early stage has persistent effects on cognitive ability ([Beckett et al., 2006](#); [Figlio et al., 2014](#)). Both these postnatal mechanisms could be correlated with both prenatal stress, and possibly public good contributions. This could therefore result in a spurious correlation between the 2D:4D digit ratio and cooperation.

We find that in our sample postnatal war exposure does not significantly affect cooperation ([Table 9](#), columns 1 and 2), and does not wash out the effect of prenatal stress. On the other hand, we find that height-for-age is positively associated with cooperation: one standard deviation increase in the height-for-age increases the likelihood of contribution to the public good by between 3% points and 6% points in the simple and fully specified models respectively. BMI-for-age and IQ-for-age do not enter significantly ([Table 9](#), columns 3 and 4). None of these indicators is however correlated with prenatal stress (see [Table A.7](#)), and prenatal stress remains significant even when controlling for these potential alternative mechanisms together: its coefficient is stable and robust to controlling for markers of early life deprivation ([Table 9](#), column 5).

Result 4. The relationship between prenatal stress and cooperation is stable and robust to controlling for early life deprivation markers and postnatal war exposure.

On top of this, we conduct a final series of robustness checks. The main result holds when we limit the sample to only blood related caregiver–child pairs, to parent–child pairs, and to mother–child pairs (see [Table A.9](#)). The result also holds when estimated using a probit model, when including school and enumerator fixed effects, and when clustering standard

Table 10

Conflict exposure predicts caregiver trauma, caregiver digit ratio does not.

	PTSD			Trauma factor		
	(1)	(2)	(3)	(4)	(5)	(6)
War exposure	0.0815*** (0.0221)	0.102*** (0.0225)	0.138*** (0.0454)	0.182*** (0.0527)	0.230*** (0.0492)	0.271*** (0.0960)
Female		0.284*** (0.0509)	0.332*** (0.0859)		0.563*** (0.106)	0.769*** (0.156)
Caregiver digit ratio			−0.0855 (1.184)			0.906 (2.220)
Caregiver controls	N	Y	Y	N	Y	Y
Sub-county fixed effects	N	Y	Y	N	Y	Y
Observations	440	438	154	440	438	154
R ²	0.028	0.105	0.157	0.033	0.129	0.229

Notes: Confidence: *** ↔ 99%, ** ↔ 95%, * ↔ 90%. Caregiver controls: Age, Female, Age × Female, Acholi, Education.

Fig. 5. Sensitivity to the unconfoundedness assumption.

errors on both school and year-of-birth levels (see Table A.6, columns 1–4). We also split our sample at the median of the digit ratio, finding that caregivers of children with low 2D:4D ratio (high prenatal stress) are not only more likely to suffer from PTSD, but also less likely to contribute to the public good (see Table A.10). The difference in PTSD rates is expected, but the difference in cooperation rates could introduce a selection bias into our results. To account for any such observable bias, we match participants using kernel matching over all our child and caregiver control characteristics, including caregiver cooperation, and perform a propensity score matching analysis on the common support area. The resulting average treatment effect is again robustly significant (see Table A.6, column 5).

5.5. Causality and unobserved selection

If certain types of caregivers – with a certain preference for cooperation or risk before the war – self-selected into or out of traumatic events, they may have passed their preferences on to the children through genetic and environmental channels. Even though we control for the preferences of caregivers, this may not suffice to net out the selection bias. One way to test whether the patterns found in Table A.10 are explained mostly by endogenous preference formation or by selection bias is to look at the relationship between the caregiver's digit ratio and their traumatisation. Table 10 shows that, while caregiver war

exposure is a strong predictor of their traumatising,²⁶ caregiver digit ratios are not. In other words, while Table 5 shows that caregiver traumatising is negatively correlated with child digit ratios, caregiver digit ratios are uncorrelated with their likelihood of being traumatised.

Again, this does not allow us to exclude all forms of self-selection. We are unable to conclusively verify the randomness of the behaviour of armed groups, or the influence of other pre-war characteristics. Our causal interpretation of the results may thus suffer from potential bias due to the omission of such unobservables. Following Blattman and Annan (2010), we provide a graphical benchmark of the sensibility of our results to exogeneity assumptions (Harada, 2013; Imbens, 2003). The curve in Fig. 5 represents the locus of partial correlation points of a hypothetical pseudo-unobservable with our assignment and outcome variables, that would reduce estimated effect below significance at the 5% level.²⁷ The selective contour is conservative, as it only reduces the coefficient size by about one quarter.²⁸ Yet, the potentially confounding mechanisms we identify and discuss above (i.e. caregiver cooperation preferences, early life deprivation, and postnatal war exposure) lie far below the selected threshold. To rule out the effect of prenatal stress, any unobserved covariate not considered in our analysis would require a partial correlation with both the treatment and the assignment well above the curve of Fig. 5.

6. Conclusions

“The womb may be more important than the home”, wrote the late Barker (1990) in his seminal work on the fetal origins of adult disease. Barker’s hypothesis has spawned a large volume of literature exploring its economic implications. This study builds upon the fetal origins literature, and tests the hypothesis that prenatal events may not only alter later-life individual abilities and health trajectories (Almond and Currie, 2011), but also social preferences. In particular, we look at the impact of prenatal stress on the preferences for cooperation among children born during an armed conflict. We play a dichotomous one-shot public goods game in Pader, a district in Northern Uganda, with children born during the 1998–2006 period of intense fighting between government forces and the Lord’s Resistance Army (LRA). Our identification strategy exploits variations in the 2D:4D digit ratio—a marker of in utero hormone exposure negatively associated with high maternal distress during early fetal development. It also exploits the assumption that war exposure and traumatising where conditionally unconfounded in our context (Blattman, 2009; Blattman and Annan, 2010; Doom and Vlassenroot, 1999; Jackson, 2002). We find that a rise in our marker of prenatal distress robustly reduces the child’s probability of contribution to the public good. The estimated effect is quantitatively large, stable, and robust to controlling for alternative mechanisms such as early life deprivation, caregiver public good contribution preferences, and war exposure after birth. We also show that it is robust to relaxing the assumption of unconfoundedness and self-selection. In other words, we show that preferences are endogenously determined right from the womb.

Our results thus support three separate findings from previous studies. Firstly – and perhaps obviously – violent conflict exposure is traumatizing. Secondly, a mother’s traumatising during pregnancy affects the hormonal balance of the fetus as observable through its 2D:4D digit ratio. Thirdly – and most importantly – in utero hormonal balance affects later-life social preferences. By analyzing these three relationships concurrently in a post-conflict context – where violence has differentially impacted large portions of the population – we find evidence supporting the entire causal chain: from conflict in one generation to economic behaviour in the next one. Prenatal stress triggers adaptive mechanisms that go far beyond the well-established relationship between postnatal war exposure and preferences. The socio-economic consequences of conflict may thus be reaching much further than previously thought, and the womb may well be far more crucial than Barker ever imagined.

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Appendix A. Tables

²⁶ We find a robustly positive and significant relationship between war exposure and trauma among caregivers, with a higher prevalence of PTSD among women. A one standard deviation increase in our war exposure index increases the likelihood of PTSD by almost 10%, and scores on the trauma factor by 20% of a standard deviation.

²⁷ H: Height-for-age; C: Caregiver cooperation; P: Postnatal war exposure.

²⁸ Blattman and Annan (2010), for instance, plot a contour that decreases the effect of the assignment by one half. This would be equivalent to shifting the contour in Fig. 5 outwards.

Table A.1
Spatial autocorrelation of war exposure and trauma

	War exposure (1)	PTSD (2)
Moran's I	−0.045	−0.030
$E(I)$	−0.024	−0.024
$sd(I)$	0.056	0.055
z	−0.364	−0.099
p -value	0.358	0.461
Observations	42	42

Notes: p -values are based on a 1-tail test.

Table A.2
Intraclass correlation of war exposure and trauma.

	War exposure (1)	PTSD (2)
ρ	0.043	0.020
Observations	440	442
Groups	42	42

Notes: ρ is the fraction of variance due to school-level random effects from a GLS regression.

Table A.3
Sensitivity of results to the exclusion of potentially biased measures

	Public good contribution			
	All (1)	$\Delta < 5\%$ (2)	$\Delta < 3\%$ (3)	$\Delta < 1\%$ (4)
Standardized digit ratio (−)	−0.081*** (0.025)	−0.109*** (0.038)	−0.103** (0.044)	0.095 (0.285)
Child controls	Y	Y	Y	Y
Caregiver and peer controls	Y	Y	Y	Y
Sub-county fixed effects	Y	Y	Y	Y
Observations	436	188	131	39
R^2	0.053	0.087	0.121	0.418
ρ	0.278	0.679	0.840	0.984

Notes: Confidence: *** $\leftrightarrow$ 99%, ** $\leftrightarrow$ 95%, * $\leftrightarrow$ 90%. Child controls: Age, Female, Age $\times$ Female; Caregiver controls: Age, Female, Age $\times$ Female, Caregiving time, Acholi, Education; Peer controls: Proportion of excluded peers, Class dummies. ρ is Pearson's correlation coefficient between first and second digit ratio measurement.

Table A.4
The relationship between the digit ratio and public good contribution is monotonic

	Cooperation			
	(1)	(2)	(3)	(4)
Standardized digit ratio (−)	−0.078*** (0.024)	−0.078*** (0.024)	−0.073*** (0.025)	−0.074*** (0.025)
Standardized digit ratio squared (−)		−0.003 (0.008)		−0.004 (0.008)
Child controls	N	N	Y	Y
Caregiver and peer controls	N	N	Y	Y
Sub-county fixed effects	N	N	Y	Y
Observations	442	442	436	436
R^2	0.025	0.025	0.085	0.085

Notes: Standard errors corrected for school level clustering (42) are in parentheses. Confidence: *** $\leftrightarrow$ 99%, ** $\leftrightarrow$ 95%, * $\leftrightarrow$ 90%. Child controls: Age, Female, Age $\times$ Female; Caregiver controls: Age, Female, Age $\times$ Female, Caregiving time, Acholi, Education, Public good contribution, Risk preferences; Peer controls: Proportion of excluded peers, Class dummies.

Table A.5

Robustness of the main result to controlling for parental digit ratios.

	Public good contribution			
	(1)	(2)	(3)	(4)
Standardized digit ratio (–)			–0.134*** (0.038)	–0.119*** (0.043)
PTSD			–0.097 (0.085)	–0.133 (0.087)
Caregiver digit ratio (biological parents only)	–0.048 (0.041)	–0.076* (0.041)	–0.060 (0.037)	–0.083** (0.039)
Child controls	N	Y	N	Y
Caregiver and peer controls	N	Y	N	Y
Sub-county fixed effects	N	Y	N	Y
Observations	154	154	154	154
R ²	0.010	0.126	0.075	0.179

Notes: Confidence: *** $\leftrightarrow$ 99%, ** $\leftrightarrow$ 95%, * $\leftrightarrow$ 90%. Child controls: Age, Female, Age $\times$ Female; Caregiver controls: Age, Female, Age $\times$ Female, Caregiving time, Acholi, Education; Peer controls: Proportion of excluded peers, Class dummies.

Table A.6

Robustness of the main result to alternative specifications.

	Public good contribution				
	Probit model (1)	School f.e. (2)	Enumerator f.e. (3)	Two-way clustering (4)	Kernel PSM (5)
Standardized digit ratio (–)	–0.082*** (0.029)	–0.064*** (0.024)	–0.057** (0.023)	–0.075*** (0.026)	–0.114** (0.054)
Child controls	Y	Y	Y	Y	Y
Caregiver and peer controls	Y	Y	Y	Y	Y
Sub-county fixed effects	Y	N	Y	Y	Y
School level clustered s.e.	42	N	42	42	N
Year of birth clustered s.e.	N	N	N	9	N
Observations	436	436	436	436	429
R ²		0.156	0.177	0.069	

Notes: Confidence: *** $\leftrightarrow$ 99%, ** $\leftrightarrow$ 95%, * $\leftrightarrow$ 90%. Child controls: Age, Female, Age $\times$ Female; Caregiver controls: Age, Female, Age $\times$ Female, Caregiving time, Acholi, Education; Peer controls: Proportion of excluded peers, Class dummies. Standard errors in (5) are bootstrapped with 100 iterations.

Table A.7

Prenatal stress does not predict markers of early life deprivation.

	Postnatal war exposure		Height-for-age		BMI-for-age		IQ-for-age	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Standardized digit ratio (–)	–0.017 (0.046)	0.031 (0.031)	–0.001 (0.056)	–0.050 (0.047)	0.083 (0.068)	0.085 (0.068)	–0.027 (0.045)	–0.038 (0.046)
Child controls	N	Y	N	Y	N	Y	N	Y
Caregiver and peer controls	N	Y	N	Y	N	Y	N	Y
Sub-county fixed effects	N	Y	N	Y	N	Y	N	Y
Observations	440	438	441	439	440	438	442	440
R ²	0.000	0.676	0.000	0.334	0.006	0.117	0.001	0.136

Notes: Standard errors corrected for school level clustering (42) are in parentheses. Confidence: *** $\leftrightarrow$ 99%, ** $\leftrightarrow$ 95%, * $\leftrightarrow$ 90%. Child controls: Age, Female, Age $\times$ Female; Caregiver controls: Age, Female, Age $\times$ Female, Caregiving time, Acholi, Education, Public good; Peer controls: Proportion of excluded peers, Class dummies.

Table A.8

Prenatal stress reduces cooperation (all coefficients).

	Public good contribution				
	(1)	(2)	(3)	(4)	(5)
Standardized digit ratio (–)	–0.072*** (0.025)	–0.070*** (0.025)	–0.073*** (0.025)	–0.073*** (0.025)	–0.074*** (0.025)
Caregiver PG contribution	0.144*** (0.041)	0.141*** (0.041)	0.144*** (0.046)	0.143*** (0.048)	0.143*** (0.047)
Caregiver risk averse	0.001 (0.054)	–0.002 (0.055)	0.007 (0.058)	0.009 (0.056)	0.008 (0.056)
Child age		0.003 (0.015)	0.017 (0.020)	0.015 (0.020)	0.015 (0.020)
Child female		–0.178 (0.243)	–0.201 (0.244)	–0.209 (0.256)	–0.218 (0.258)
Child age × female		0.016 (0.021)	0.018 (0.021)	0.019 (0.022)	0.020 (0.022)
Caregiver age			–0.005 (0.003)	–0.005 (0.003)	–0.005 (0.003)
Caregiver female			–0.332* (0.176)	–0.332* (0.176)	–0.340* (0.177)
Caregiver age × female			0.009** (0.004)	0.009** (0.004)	0.010** (0.004)
Caregiving time			–0.089 (0.102)	–0.092 (0.099)	–0.095 (0.098)
Caregiver Acholi			0.007 (0.120)	–0.010 (0.144)	–0.006 (0.150)
Caregiver education			0.015 (0.037)	0.014 (0.038)	0.011 (0.039)
Proportion of excluded peers			–0.481* (0.280)	–0.528 (0.337)	–0.545 (0.347)
P2			0.114 (0.077)	0.110 (0.078)	0.112 (0.078)
P6			0.011 (0.063)	0.014 (0.063)	0.010 (0.064)
Lira Palwo sub-county				–0.034 (0.077)	–0.046 (0.079)
Lukole sub-county				–0.056 (0.081)	–0.063 (0.083)
Parabongo sub-county				–0.028 (0.083)	–0.037 (0.085)
Patongo sub-county				–0.093 (0.160)	–0.096 (0.156)
Awere sub-county				–0.068 (0.084)	–0.070 (0.091)
Pajule sub-county				0.022 (0.101)	0.011 (0.102)
Puranga sub-county				–0.020 (0.086)	–0.021 (0.091)
Child risk preferences					0.004 (0.046)
Child time preferences					–0.028 (0.058)
Household size					0.007 (0.009)
Asset index					0.006 (0.019)
Observations	442	442	436	436	436
R ²	0.046	0.050	0.082	0.085	0.088

Notes: Standard errors corrected for school level clustering (42) are in parentheses. Confidence: *** ↔ 99%, ** ↔ 95%, * ↔ 90%. Atanga sub-county is taken as reference category, and therefore omitted.

Table A.9

Sensitivity of results to caregiver relationship to the child.

	Public good contribution			
	All (1)	Blood-related (2)	Parents (3)	Mothers (4)
Standardized digit ratio (–)	–0.080*** (0.025)	–0.079*** (0.025)	–0.082*** (0.028)	–0.083** (0.034)
Child controls	Y	Y	Y	Y
Caregiver and peer controls	Y	Y	Y	Y
Sub-county fixed effects	Y	Y	Y	Y
Observations	436	435	348	187
R ²	0.065	0.063	0.070	0.127

Notes: Standard errors corrected for school level clustering (42) are in parentheses. Confidence: *** $\leftrightarrow$ 99%, ** $\leftrightarrow$ 95%, * $\leftrightarrow$ 90%. Child controls: Age, Female, Age $\times$ Female; Caregiver controls: Age, Female (excluding column 4), Age $\times$ Female (excluding column 4), Caregiving time, Acholi, Education; Peer controls: Proportion of excluded peers, Class dummies.

Table A.10

Split-sample balance (caregivers).

Variable	High child 2D:4D		Low child 2D:4D		Diff.	Std. err.
	(Low prenatal stress)		(High prenatal stress)			
	Obs.	Mean	Obs.	Mean		
2D:4D	76	0.957	78	0.956	−0.001	0.006
Public good contribution	221	0.561	221	0.452	−0.109**	0.047
Age	220	42.3	220	41.8	−0.5	1.1
Female	221	0.489	221	0.579	0.090*	0.047
Caregiving time	219	0.893	219	0.917	0.024	0.018
Education level	221	0.864	221	0.814	−0.050	0.076
Risk preferences	221	0.299	221	0.326	0.027	0.044
War exposure	220	0.746	220	0.758	0.012	0.016
PTSD (dummy)	221	0.317	221	0.466	0.149***	0.046
PTSD (factor)	221	−0.142	221	0.142	0.284***	0.094
Christian	221	0.977	221	0.968	−0.009	0.015
Acholi	221	0.995	221	0.986	−0.009	0.009
Household size	221	7.92	221	8.26	0.34	0.28
Assets index	221	−0.028	221	0.028	0.056	0.095

Notes: Confidence: *** $\leftrightarrow$ 99%, ** $\leftrightarrow$ 95%, * $\leftrightarrow$ 90%.

Appendix B. Figures

Fig. B.1. Average war exposure per school.

Fig. B.2. Private and group cards in the public goods game for children.

Appendix C. Variable definitions

2D:4D. A child level measure of the relative length of the index finger of the right hand with respect to the ring finger (in cm).

Standardised digit ratio (–). A child level variable derived by standardizing the 2D:4D (z-score). The negative sign is added for ease of interpretation.

Public good contribution (child and caregiver). An individual level dummy for both child and caregiver representing the individual choice in the public goods game: “group card” or “private card”. The choice “group card” takes value 1, 0 otherwise.

Age (child and caregiver). Age of respondent (child and caregiver) i in years, rounded down to the last birthday.

Female (child and caregiver). Individual level dummy taking value of 1 if respondent (child and caregiver) is female, 0 otherwise.

Class dummies (P2, P4, P6). Child-level dummies indicating the current school grade of child i .

Height-for-age. The height of child i standardised for his age class (de Onis et al., 2007).

BMI-for-age. The body-mass-index of child i standardised for his age class (de Onis et al., 2007).

IQ-for-age. The IQ of child i , measured using standard Raven’s matrices and standardised for his age class (in sample).

Time preferences. A child level dummy taking value of 1 if child prefers to receive two candies at the end of the survey rather than one half way, 0 otherwise.

Risk preferences (child). A dummy equal to 1 if the child consistently chooses for the riskier option in a two dichotomous lottery choices; 0 otherwise.

Risk preferences (caregiver). A dummy equal to 0 if the caregiver chose the least risky one of several lottery options; 1 otherwise.

War exposure (child and caregiver). A caregiver level victimisation index derived from answers to 23 war witnessing questions (see Mackoud, 1992). The postnatal war exposure of child i is proxied by the war exposure of the caregiver multiplied by the fraction of violent conflict events that took place after the birth of child i .

Caregiving time. The fraction of a child’s life for which the interviewed adult was their primary caregiver.

Education level. A caregiver level variable indicating the number of completed years of education.

PTSD. A caregiver level measure of post-traumatic stress disorder, calculated using the PCL-civilian checklist.

Christian. A dummy taking value of 1 if the caregiver is Christian by religion, 0 otherwise.

Acholi. A dummy taking value of 1 if the caregiver is ethnically Acholi, 0 otherwise.

Household size. The number of people sharing the same roof and sharing the same pot.

Assets index. A principal factor (see Sahn and Stifel, 2003) of assets possessed by the caregiver’s household.

Supplementary material

Supplementary material associated with this article can be found, in the online version, at [10.1016/j.euroecorev.2017.09.015](https://doi.org/10.1016/j.euroecorev.2017.09.015).

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