Age of Marriage, Weather Shocks, and the Direction of Marriage Payments*

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Abstract

We study how aggregate economic conditions affect the timing of marriage, and particularly child marriage, in Sub-Saharan Africa and in India. In both regions, substantial monetary or in-kind transfers occur with marriage: bride price across Sub-Saharan Africa and dowry in India. In a simple equilibrium model of the marriage market in which parents choose when their children marry, income shocks affect the age of marriage because marriage payments are a source of consumption smoothing, particularly for a woman's family. As predicted by our model, we show that droughts, which reduce annual crop yields by 10 to 15%, have opposite effects on the marriage behavior of a sample of 400,000 women in the two regions: in Sub-Saharan Africa, they increase the annual hazard into child marriage by 3%, while in India droughts reduce such a hazard by 4%. Changes in the age of marriage due to droughts are associated with changes in fertility, especially in Sub-Saharan Africa, and with declines in observed marriage payments. Our results indicate that the age of marriage responds to short-term changes in aggregate economic conditions and that marriage payments determine the sign of this response. This suggests that, in order to design successful policies to combat child marriage and improve investments in daughters' human capital, it is crucial to understand the economic role of culture.

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Marriage markets are an important determinant of human capital investments, risk-sharing opportunities and fertility outcomes (Tertilt, 2005; Field and Ambrus, 2008; Chiappori, Dias, and Meghir, 2018). Across countries and over time, different trends in marriage behavior, and especially in the age of marriage, are associated with vastly different economic opportunities for women and demographic outcomes. Yet, limited empirical research has examined whether aggregate economic forces influence marriage decisions and marriage markets, particularly in developing countries, where marriage is often regulated by traditional customary norms. Our paper shows that aggregate shocks have sizable effects on the marriage behavior of women living in developing countries, with significant demographic consequences, and that the cultural practices regulating marriage play a crucial role in explaining this response, in line with a simple economic model. Hence, in order to understand how marriage markets work and how they interact with economic variables, it is crucial to study the culture and institutions that regulate marriage.

In particular, we investigate the economic determinants of the timing of marriage for women and focus especially on child marriage (defined as marriage before the age of 18), a widespread and dramatic phenomenon among women in the developing world, that has been linked to poor educational, socioeconomic and health outcomes for both women and their children. We study two regions of the world, Sub-Saharan Africa and India, where, despite improvements in female educational and economic opportunities, a large number of women continue to marry at an early age and where there is a persistent tradition of marriage payments: throughout Sub-Saharan Africa, it is customary for the groom or his family to pay a bride price to the bride's family, whereas in India, the prevailing tradition is for the bride's family to pay a dowry to the groom or his family at the time of marriage. In these regions, child marriage is strongly associated with poverty: it is more prevalent in poorer countries, and within each country, among the poorest households (UNICEF, 2014a).

How do aggregate economic conditions affect marriage decisions, and particularly child marriage in developing countries? Do traditional marriage payment norms influence such a relationship? To study these questions, we develop an equilibrium model of child marriage. Families choose when their children marry and societies are virilocal, i.e. women move to the groom's family upon marriage. When aggregate income is temporarily low, marginal utility of consumption is higher, and households prefer to bring forward (with bride price) or delay (with dowry) their daughter's marriage in order to consume the marriage transfer. In equilibrium, however, the grooms' families are also affected by the same aggregate shocks. Hence, equilibrium marriage payments fall with negative income shocks and equilibrium quantities vary depending on which side of the market is more sensitive to the price decline. Because of virilocality, we show that, in equilibrium, child marriages increase under bride price and decrease under dowry, because a man's parents value future marriage transfers less if they can rely on their son's economic support in older age, compared to a woman's parents, who are less likely to benefit from a daughter's support after she is married. Hence, the relationship between aggregate income realizations and the timing of marriage in equilibrium is not univocal: its sign changes depending on the cultural norms regarding the direction of the marriage payments, i.e. whether bride price or dowry prevails.

To test the implications of our model, we examine the effect of rainfall shocks –a major source of income variability in areas that rely on rain-fed agriculture– on the hazard into child marriage among women in Sub-Saharan Africa and India. We combine rainfall data from the University of Delaware Air Temperature and Precipitation project (UDel) between 1950 and 2010 with marriage information from 73 pooled Demographic and Health Surveys (DHS) from 31 Sub-Saharan African countries between 1994 and 2013 and from the 1998-1999 India DHS.[1] We henceforth obtain information on the age of marriage and on the history of rainfall shocks for approximately 400,000 women for every year between age 12 and age 24 born between 1950 and 1989. To investigate the effect of rainfall shocks on agricultural output, we also merge the UDel data with historical data on crop yields provided by the Food and Agricultural Organization (FAO) and by the World Bank. In both regions, a drought, defined as an annual rainfall realization below the 15th percentile of the local rainfall distribution, is associated with a significant 10 to 15% decline in agricultural production.

Our main results indicate that, as predicted by our model, droughts have opposite effects on early marriage in Sub-Saharan Africa and in India, despite having similar negative effects on crop yields: while in Sub-Saharan Africa low realizations of rainfall increase the hazard of marriage before age 25 and before age 18, we find that in India they reduce such a hazard. The effects are sizable and concentrated on child marriage: a drought raises the annual hazard of marriage between ages 12 and 17 by 3% in Sub-Saharan Africa, and it decreases it by 4% in

[1] We verify robustness of these findings in the 2005 Indian Human Development Survey (IHDS).

India. These findings are robust to a wide set of alternative definitions of rainfall shocks and alternative sample specifications.

After establishing that droughts have large effects on the timing of marriage, we examine an important implication of early marriage: early fertility. We show that in Sub-Saharan Africa, a drought is associated with a 4% increase in the annual probability of having a child before turning 18. An additional drought episode during teenage years reduces the age of marriage by 0.04-0.05 years and increases the total number of children a woman reports by 0.06 or 1%. As expected, such effects are not observed in India.

To study whether indeed the direction of marriage payments can explain these differential patterns, we examine heterogeneity between and within countries.

First, within Sub-Saharan Africa, we exploit historical data on heterogeneity in marriage payments traditions across ethnic groups, showing that the positive effect of droughts on the hazard into child marriage is concentrated within countries and ethnic groups that traditionally pay bride price at marriage. We find no effect in countries where less than half of the population traditionally engages in bride price payments and in Eritrea, a country where dowry is prevalent, we document a negative effect of droughts on child marriage, similar to the one documented in India.

Second, within India, where nowadays dowry prevails across regions, casts and religious groups, we find that the effect of rainfall shocks on the hazard into child marriage is concentrated among Hindus, among whom the practice originated, within regions where dowry is traditionally practiced. We find no effects for the oldest cohorts in the South of the country, where dowry was only introduced over the past few decades, but a sizable effect for more recent cohorts.

We follow multiple approaches to additionally study the mechanisms underlying the effect of droughts on the age of marriage within each context, and test whether they are consistent with the setup of our model. First, we examine heterogeneity in the effect of dowry on child marriage according to the intensity by which droughts affect crop yields, income and consumption. We find strong evidence that when droughts have a greater impact on a household consumption, because of lack of irrigation technology, credit markets, unfavorable agro-ecological conditions, or unfavorable household composition, the effect of droughts on child marriage is stronger. Second, we study how the presence of biased sex ratios in India may again exacerbate the effect of droughts on child marriage, in agreement with our model. Third, we investigate whether payments for marriages that occur during droughts are indeed lower, as predicted by our model. To do so, we exploit additional available data on dowry payments in India from the 1998 Rural Economic and Demographic Survey (REDS) and on bride price payments from the Indonesia Family Life Survey (IFLS), as no extensive data from Africa is available. In both countries, we find that transfers paid for marriages that occur during droughts are substantially lower than those paid during normal times, consistent with the predictions of our model: in India, a drought at the district level is associated with 15% lower dowry payments, while in Indonesia, a drought at the province level is associated with 45% lower bride price payments. Controlling for observable characteristics of the match does not affect these estimates, suggesting that indeed marriage payments are likely to drop with aggregate negative economic shocks.

Our paper is related to three main strands of the literature in economics. The first is the literature on how marriage markets work (Abramitzky, Delavande, and Vasconcelos, 2011; Banerjee, Duflo, Ghatak, and Lafortune, 2013; Chiappori, Salanié, and Weiss, 2017) and how they interact with economic outcomes (Tertilt, 2005; Greenwood, Guner, and Vandenbroucke, 2017), especially in developing countries. There is only limited and discordant evidence about how the business cycle affects marriage behavior in developed or in developing countries (Schaller, 2013; Autor, Dorn, and Hanson, forthcoming; Brandt, Siow, and Vogel, 2016), and more generally about how short-term changes in economic incentives influence marriage behavior. The existing empirical evidence broadly suggests that economic forces have at best small effects on the marriage market. We contribute to this literature by showing that, where marriage payments are customary, temporary aggregate income shocks lead to substantial shifts in the timing of marriage, particularly at the crucial early ages, in the timing of fertility and in the fertility rate. These findings suggest that economic policies that modify the incentives to marry in the short run can have lasting effects on women's marital and fertility outcomes.[2]

Second, this paper fits within the broad body of research on the importance of culture and institutions in shaping economic behavior. Much of this work has studied the role of cultural values and beliefs, such as trust, family ties, and gender norms on economic development (Fernandez, Fogli, and Olivetti, 2004; Fernandez and Fogli, 2009; Guiso, Sapienza, and Zingales,

[2] These insights are particularly valuable given increasing worldwide calls to eliminate child marriage. According to recent estimates by the World Bank, eliminating child marriage and child fertility could reduce fertility rates and population growth rates by 10% in high-prevalence countries, generating over $500 billion in annual benefits each year, through a reduction in deaths and malnutrition among young children and through increased female labor market earnings and productivity, among other channels (Wodon, Male, Nayihouba, et al., 2017).

2006; Tabellini, 2010; Nunn and Wantchekon, 2011). A growing part of this literature has explored the influence of culture and institutions on determinants of economic development (Platteau, 2000; Jacoby, 1995; Tertilt, 2005; La Ferrara, 2007; La Ferrara and Milazzo, 2017; Jayachandran and Pande, forthcoming). While marriage payments are widespread in many regions in Africa and Asia, only a few studies have examined their effect on households' economic decision, such as female education and health (Bishai and Grossbard, 2010; Anderson and Bidner, 2015; Ashraf, Bau, Nunn, and Voena, forthcoming; Bhalotra, Chakravarty, and Gulesci, 2018). In this paper, we show that these payments significantly influence how the marriage market works, generating opposite responses to the same economic circumstances. These findings are an example of how culture may influence the external validity of natural experiments, by radically modifying the economic relationship between variables. Hence, understanding their role can contribute to policy design and evaluation: for example, our framework suggests that income stabilization policies, like crop insurance or unconditional cash transfers, could reduce child marriage in some countries, but increase it others. A deep understanding of the mechanisms that regulate the marriage market can shed light on what the most effective policies to address child marriage in each context are. Our findings emphasize the value of replicating empirical and experimental analyses in different environments and highlight the role of cultural norms as variables that may be relevant for extrapolation (Dehejia, Pop-Eleches, and Samii, 2015).

Third, our results contribute to the large economic literature that investigates the coping mechanisms used by poor households to deal with income risk. Despite imperfect markets for formal insurance, rural households seem well-equipped to smooth consumption in the face of short-term, idiosyncratic income shocks, often through informal insurance arrangements (Townsend, 1994). However, in the face of aggregate shocks, households must rely on a different set of strategies to cope, such as seasonal migration, off-farm employment, and liquidation of buffer stock (Fafchamps, Udry, and Czukas, 1998; Kazianga and Udry, 2006; Jayachandran, 2006; Morten, forthcoming). These strategies are typically unable to provide full consumption smoothing, as illustrated by the growing empirical literature showing a detrimental effect of drought on infant and child health, schooling attainment and performance, and domestic violence.[3] In this paper, we show that households use female child marriage as a strategy to cope with income volatility, bringing it forward when a payment is expected and delaying it when a payment is due.

[3]See Dell, Jones, and Olken 2013 for a comprehensive review of this literature.

Households make irreversible decisions even in response to short-term shocks, in order to smooth consumption. This behavior has dramatic long-run welfare implications for young women and their offspring, thus contributing to gender inequality and lower accumulation of human capital.

The remainder of the paper proceeds as follows. Section 1 provides background information on marriage markets, marriage payments, and child marriage in Sub-Saharan Africa and in India. Section 2 illustrates the model. Section 3 describes the data used in the analysis, and section 4 explains the empirical strategy. Sections 5 and 6 show the main empirical results and provide robustness checks. Section 7 brings in additional data sources to explore the mechanisms underlying our main effects. Section 8 concludes.

1 Background

In this section we discuss the consequences and the theories about the persistence of child marriages around the world and provide some background on marriage payments in Sub-Saharan Africa and India.

1.1 Age of marriage and child marriage

Child marriage is still a dramatic practice in many countries around the world. Worldwide, more than 700 million women alive today were married before their 18th birthday and 25 million entered into union before the age of 15. Child marriage, defined as marriage before the age of 18, is especially pronounced among women living in Sub-Saharan Africa and South Asia. Estimates from UNICEF suggests that 56% and 42% of women between 20 to 49 got married before the age of 18 respectively in South Asia and in Sub-Saharan Africa (UNICEF, 2014b). Child marriage is associated with a wide range of adverse outcomes for women and their offspring, including higher rates of domestic violence; harmful effects on maternal, newborn, and infant health; reduced sexual and reproductive autonomy; lower literacy and educational attainment (Jensen and Thornton, 2003; Field and Ambrus, 2008; Chari, Heath, Maertens, and Fatima, 2017). Based on these findings, international organizations such as UNICEF and the World Bank have called for "urgent action", arguing that the eradication of child marriage is a necessary step towards improving female human capital accumulation, empowerment and autonomy around the world.[4] Despite the brutal consequences of early marriage and policy action taken to reduce it, the causes of this phenomena has been so far seldom examined in the economic literature and not well understood.

There are many potential reasons why this practice has persisted. Parents often view child marriage as a socially acceptable strategy to protect their daughter against events, like sexual assault or out-of-wedlock pregnancy, that could compromise her purity and subsequent marriageability (see for example World Vision 2013). Grooms also tend to express a preference for younger brides, purportedly due to beliefs that younger women are more fertile, more likely to be sexually inexperienced and easier to control (Field and Ambrus, 2008). Although culture is considered an important driver of the persistence of child marriage, economic conditions may also play a role. Poverty is strongly associated with child marriage worldwide (Harper, Jones, Presler-Marshall, and Walker, 2014). Girls from poor households are almost twice as likely to marry early as compared to girls from wealthier households (Klugman, Hanmer, Twigg, Hasan, McCleary-Sills, and Santamaria, 2014). In Sub-Saharan Africa and South Asia, this relationship is likely to interact with the widespread tradition of marriage payments. Indeed, the limited empirical evidence available suggests that dowry is increasing in a bride's age, while bride price is at first increasing and then rapidly decreasing in a bride's age, meaning that under both customs, marrying a daughter earlier can be financially more attractive for her parents.[5] Hoogeveen, Van Der Klaauw, and Van Lomwel (2011) hypothesize that bride wealth is a source of insurance against the loss of livestock, but find no empirical relationship between the timing of marriage and rainfall in rural Zimbabwe. In a companion apper to this study, Corno and Voena (2017) show that child marriage responds to income shocks in rural Kagera, Tanzania, where bride price is customary and there is no variation in marriage payment practices. To the best of our knowledge, ours is the first paper to systematically study the relationship between child marriage, economic shocks and marriage payments.

[4] See UNICEF 2014b.

[5] For evidence on the relationship between dowry and bride's age in India, see Chowdhury (2010). Arunachalam and Naidu (2010) study the relationship between fertility and dowry. Empirical data on bride price is limited, but for evidence on bride price and bride's age in the Kagera Health and Development Survey from Tanzania, see Corno and Voena (2017).

1.2 Marriage payments

Marriage payments, i.e. bride price and dowry, are widespread in developing countries. The prevailing economic view of marriage payments is based on the seminal work by Becker (1991). These payments may emerge as pecuniary transfers to clear the market when the rules for the division of household output are inflexible. In cases where the woman's shadow price on the marriage market is less than her share of household output, a bride price will emerge to encourage her to marry; in the opposite case, dowries will emerge to encourage men's participation in the marriage market.[6] Marriage payments may hence also emerge in response to scarcity on one side of the marriage market.

There is an important difference between marital customs in sub-Saharan Africa and India: in many Sub-Saharan African countries, bride price is the prevailing norm, while in India, dowry is the most common practice. Traditionally, the practices of bride price was near-ubiquitous across and within Sub-Saharan Africa countries: more than 90% of ethnic groups in Sub-Saharan Africa traditionally paid bride price (see Goody (1976); Murdock (1967) and Appendix table A1) and there exists wide evidence that the practice has persisted to the present day, although empirical evidence is relatively scarce.[7]

A wider body of literature has examined the causes and consequence of dowry in India (Anderson, 2003; Sautmann, 2017; Edlund, 2006). Interestingly, although dowry has been practiced in Northern India for centuries, it is a much more recent phenomenon in the South, where bride price traditions were formerly the norm (Caldwell, Reddy, and Caldwell, 1983; Srinivasan, 2005). In the time period of our study, dowry is widespread across India and payments are large

[6] Traditionally, dowry appears to have served mainly as a pre-mortem bequest made to daughters rather than as a payment used to clear the marriage market (Goody and Tambiah, 1973). However, with development, dowry appears to have taken on a function more akin to a groomprice, a price that brides' parents must pay in order to ensure a husband for their daughter. The transition of the property rights over dowry from the bride to her husband is studied in Anderson and Bidner (2015), who document a similar transition in late-middle ages in Europe. The view of dowry as a pre-mortem bequest to daughters is also at odds with the prevalence of dowry violence in India, whereby grooms threaten domestic violence in order to get higher transfers from their wife's parents (see Bloch and Rao 2002; Sekhri and Storeygard 2014).

[7] For example, a household panel survey conducted in Zimbabwe in the mid-1990s revealed near-universality of bride price at the time of marriage; average bride wealth in this data (received primarily in the form of cattle) was estimated to be two to four times a household's gross annual income, although partly paid in installments (Decker and Hoogeveen, 2002). Relying on DHS data, Anderson (2007a) reports that bride price was paid in about two-thirds of marriages in rural Uganda in the 1990s, down from 98% in the period between 1960-1980 and 88% from 1980-1990. In a large-scale survey conducted by Mbaye and Wagner (2013) in rural Senegal in 2009-2011, bride price was paid in nearly all marriages. Ashraf, Bau, Nunn, and Voena (forthcoming) document that the practice is widespread in modern-day Lusaka (Zambia), with payments often exceeding annual per capita GDP.

in magnitude, often significantly above average household income (Anderson, 2007b; Anukriti, Kwon, and Prakash, 2018).

The pioneering work on marriage payments in economics has focused on historical data from Europe (Botticini and Siow, 2003), where it served primarily a pre-mortem bequest function. There are several explanations proffered to explain the existence of dowry in India and bride price in Africa. Boserup (1970) offers an hypothesis based on differences in women's agricultural productivity in the two regions. She argues that in Africa, which historically did not rely on the plough technology but makes extensive use of light tools, female labor is more valuable than in Asia, a region characterized by plough agriculture, and this generates marriage payments to move towards the bride's side of the market. This hypothesis finds empirical support in Giuliano (2015) who documents a positive correlation between women's role in agriculture and the direction of marriage payments.[8] In the theoretical framework we present below, we hence follow this hypothesis as the historical source of variation in marriage payment norms across countries (see also Grossbard (1978)).

2 The model

In this section, we develop a simple equilibrium model to study how aggregate income fluctuations affect child marriage. We show under what assumptions marriage payments play a crucial role in this setting and determine whether more or fewer women marry early when aggregate income is low.

2.1 Setup

There is a unit mass of households with a daughter and a unit mass of households with a son. There are two periods, which correspond to two life stages for a woman, childhood ($t = 1$) and adulthood ($t = 2$).[9] The discount factor is denoted by δ. There is no borrowing nor saving

[8] In a partly different interpretation, Goody and Tambiah (1973) argue that land abundance and low population density can explain the prevalence of bride price in Africa. The relative scarcity of labor requires men to compensate the bride's family for losing her labor, and increases the value of the woman's ability to produce offspring. In contrast, in South Asia, where population density is high and land is scarce, men differ substantially in their land holdings, and women's own labor and ability to reproduce is relatively less valuable.

[9] Because men tend to be older than their wife at marriage, period 1 may correspond to childhood for a woman and typically to young adulthood for a man.

(incomplete markets). Each household decides whether or not to have their child marry.[10]

Preferences Households have Constant Relative Risk Aversion utility $u(c) = \frac{c^{1-\gamma}}{1-\gamma}$ over consumption in each period, for $\gamma \geq 1$.

Income In each period, household income is equal to

$$y_t + \epsilon_t.$$

Aggregate income y_t can be high (y^H) or low with (y^L) with equal probability, depending on the weather realization. Idiosyncratic income ϵ_t is distributed according to pdf $f()$ and cdf $F()$. These component are independent and serially uncorrelated.

Children's contributions to household consumption In addition to aggregate and idiosyncratic income, children contribute to household budget constraint. Children's contribution to the household consumption is denoted by w_t^s where $s \in \{f, m\}$. A son is always productive: $w^m > 0$. A daughter may or may not be productive: when $w_t^f > 0$, she contributes more to household consumption compared to how much she consumes, while when $w^f < 0$, she contributes less than she consumes. In what follows, we will only require that $w_t^m > w^f$, i.e. that sons are more productive than daughters. Based on the literature on the historical origins of the direction of marriage payments (Boserup, 1970), we denote as $\tilde{w}_t^f$ the *historical* w_t^f, with $\tilde{w}_2^f > 0$ in most of Sub-Saharan Africa and $\tilde{w}_2{}^f < 0$ in India. In the main proofs, for simplicity, we will assume that these contributions are not directly affected by aggregate shocks ($\frac{dw_t^s}{dy_t} = 0$), but in the appendix we discuss the robustness of our findings to relaxing this assumption.

Marriage The society is virilocal, i.e. upon marriage women move to the groom's family and contribute to its budget. The utility that a family obtains from the marriage of their son or daughter is denoted by $\xi^s \geq 0$ for $s \in \{f, m\}$.[11]

Marriage payments We define $\tau_t > 0$ a payment from the groom's family to bride's family (bride price) and $\tau_t < 0$ a payment from the bride's family to the groom's family (dowry) which occurs in period t, at the same time as the marriage.

Payoffs We denote as $U_t^s(b_t|M_{t-1})$ the utility in period $t = 1, 2$ of the family with child $s = f, m$, depending on whether their child marries in period 1 ($b_1 = 1$) or marries in period

[10] An interesting extension would be to incorporate parental altruism (Doepke and Zilibotti, 2017). Here, we model the parents as authoritarian.

[11] For example, in virilocal societies like the ones we are studying, ξ^m can capture the utility of acquiring offspring. The parameters ξ^f may also capture the (inverse of the) social stigma associated with having an unmarried daughter.

2 ($b_2 = 1$) or never marries ($b_1 = 0, b_2 = 0$). The variable M_{t-1} is a state variable that takes value 1 if the person is married at the beginning of period t and 0 otherwise. Note that $M_0 = 0$ (everyone is unmarried at the beginning) and that $b_2 = 0$ if $M_1 = 1$ (people only marry once).

2.2 Adulthood

In adulthood, households are price takers. Given the marriage choice b_2, payoffs for families of children who are unmarried at the beginning of period 2 are

$$U_2^f(b_2|M_1 = 0, y_2, \epsilon_{2i}, \tau_2) = u\left(y_2 + \epsilon_{2i} + w_2^f + b_2 \cdot (\tau_2 - w_2^f)\right) + b_2 \cdot \xi^f$$
$$U_2^m(b_2|M_1 = 0, y_2, \epsilon_{2i}, \tau_2) = u\left(y_2 + \epsilon_{2j} + w_2^m - b_2 \cdot (\tau_2 - w_2^f)\right) + b_2 \cdot \xi^m$$

while payoffs for families of children who are already married are

$$U_2^f(b_2|M_1 = 1, y_2, \epsilon_{2i}) = u\left(y_2 + \epsilon_{2i}\right) + \xi^f$$
$$U_2^m(b_2|M_1 = 1, y_2, \epsilon_{2j}) = u\left(y_2 + \epsilon_{2j} + w_2^m + w_2^f\right) + \xi^m.$$

The value of being unmarried at the start of period 2 is defined as $V_2^s(M_1 = 0, y_2, \epsilon_2)$.

2.2.1 Historical origins of marriage payments

When total income is sufficiently low, a payment τ_2 may be required for household to consent to marriage. Following Boserup's interpretation, the direction of the marriage payment may be due to the historical sign of a woman's contribution $\tilde{w}^f$. When historically women were productive ($\tilde{w}_2^f > 0$) letting go of a daughter would be worse than keeping her at home even for the richest household.[12] In this case, a bride price payment ($\tau_2 > 0$) would be needed to persuade women's parents to let their daughter marry. When historically women were costly ($\tilde{w}_2^f < 0$), welcoming a son's bride into the household may be too costly even for the richest household, and a dowry payment may be required.[13] In this case, a dowry payment ($\tau_2 < 0$) would persuade a man's family to accept a bride into their household.

We model household behavior as price-taking. Households will accept to marry their child

[12]This instance would arise when $u(y^H + 1 + \tilde{w}_2^f) > u(y^H + 1) + \xi^f$.

[13]This instance would arise when $u(y^H + 1 + w_2^m) > u(y^H + 1 + w_2^m + \tilde{w}_2^f) + \xi^m$.

given transfer τ_2 if and only if

$$U_2^s(b_2 = 1|M_1 = 0, y_2, \epsilon_2, \tau_2) \geq U_2^s(b_2 = 0|M_1 = 0, y_2, \epsilon_2, \tau_2).$$

Any transfer that satisfies this condition for both sides of the marriage market can be an equilibrium marriage payment τ_2^*. One example is $\tau_2^* \in [\underline{\tau}_2, \bar{\tau}_2]$ to be equal to $\tilde{w}_2^f$, which would correspond the the case in which the man historically made a take-it-or-leave-it offer to the bride's family when her family does not have a utility gain from the daughter's marriage.

Proposition 1. *There exists a non-empty interval* $[\underline{\tau}_2, \bar{\tau}_2]$ *such that, with marriage transfer* $\tau_2^* \in [\underline{\tau}_2, \bar{\tau}_2]$*, everyone who is single at the beginning of the second period marries. When the gains from marriage* ξ^s *are sufficiently large, such an interval includes values of* τ_2^* *such that* $sign(\tau_2^*) = sign(\tilde{w}_2^f)$ *irrespective of present-day* w^f*, as long as consumption is strictly positive.*

The goal of the proposition is to state that whether in adulthood bride price ($\tau_2^* > 0$) or dowry ($\tau_2^* < 0$) prevails is due to culture, intended as a way of selecting among multiple equilibria (Greif, 1994).

2.3 Childhood

For a given transfer τ_1 paid in marriages that occur in the first period, payoffs are

$$U_1^f(b_1|M_0 = 0, y_1, \epsilon_{1i}) = u\left(y_1 + \epsilon_{1i} + w_1^f + b_1(\tau_1 - w_1^f)\right) + \delta E\left[V_2^f(M_1)\right]$$
$$U_1^m(b_1|M_0 = 0, y_1, \epsilon_{1j}) = u\left(y_1 + \epsilon_{1j} + w_1^m - b_1(\tau_1 - w_1^f)\right) + \delta E\left[V_2^m(M_1)\right].$$

A woman or a man will want to get married in the first period if and only if:

$$U_1^s(b_1 = 1|M_0 = 0, y_1, \epsilon_1) > U_1^s(b_1 = 0|M_0 = 0, y_1, \epsilon_1).$$

This implies that for any marriage to occur in childhood, the bride price payment needs to be larger than the woman's contribution to her parents' budget ($\tau_1 \geq w_1^f$) and a dowry needs to be larger than a woman's cost to her in-laws' budget ($\tau_1 \leq w_1^f$).

Proposition 2. *There exist two thresholds of idiosyncratic income,* $\epsilon_f^*(\tau_1, y_1)$ *and* $\epsilon_m^*(\tau_1, y_1)$*, which determine the marriage decision in the first period. With bride price, all women with*

$\epsilon_{1i} \leq \epsilon^*_f(\tau_1, y_1)$ and all men with $\epsilon_{1j} \geq \epsilon^*_m(\tau_1, y_1)$ will want to marry in the first period. With dowry, all women with $\epsilon_{1i} \geq \epsilon^*_f(\tau_1, y_1)$ and all men with $\epsilon_{1j} \leq \epsilon^*_m(\tau_1, y_1)$ will want to marry in the first period.

Proof. See Appendix A. □

2.3.1 Demand and supply functions

The cumulative density associated with the thresholds determine the supply and demand functions for brides. We will consider only values of τ_1 and y_1 for which these thresholds lie within the support of $F()$ on both sides of the market, these being the relevant cases in our empirical setting.

Proposition 3. *When bride price prevails, the supply of brides $(S(\tau_1, y_1))$ is decreasing in aggregate income y_1 and the demand for brides $(D(\tau_1, y_1)))$ is increasing in aggregate income y_1. When dowry prevails, the supply of brides is increasing in aggregate income y_1 and the demand for brides is decreasing in aggregate income y_1.*

Proof. See Appendix A. □

2.3.2 Equilibrium in the marriage market

The equilibrium marriage payment which clears the marriage market in the first period is the one that solves $D(y_1, \tau_1^*) = S(y_1, \tau_1^*)$. This price determines the equilibrium quantity of child marriage $Q_1^*(y_1)$.

Proposition 4. *When bride price prevails and w^m is sufficiently large, lower aggregate income y_1 increases child marriage in equilibrium $\left(\frac{dQ_1^*(y_1)}{dy_1} < 0\right)$. When dowry prevails and w^m is sufficiently large, lower aggregate income y_1 decreases child marriage in equilibrium $\left(\frac{dQ_1^*(y_1)}{dy_1} > 0\right)$.*

Proof. See Appendix A. □

To understand this result intuitively, first consider the case in which the supply and demand are equally income-elastic ($|S_y| = |D_y|$) and equally price-elastic ($S_\tau = |D_\tau|$). Aggregate income shocks will have no effect on quantity in this instance. Now suppose that supply is more income-elastic than demand ($|S_y| > |D_y|$). Under bride price, this implies that lower aggregate income will result in a higher quantity of child marriage. On the other hand, under dowry, lower aggregate income will result in a lower quantity of child marriage. Lower aggregate income will have similar quantity effects if supply and demand are equally income elastic, but demand is more price elastic than supply ($S_\tau < |D_\tau|$), since lower aggregate income decreases τ under bride price, but increases it (i.e. makes τ less negative) under dowry. The proof of the proposition relies on the fact that these conditions are more likely to be true when the income provided by a son w^m is large enough, particularly relative to that provided by a daughter w^f.

It is important to point out that, as long as the sons remain more productive than daughters during droughts, this proposition is robust to allowing the children's contribution to the household budget constrain to decrease during droughts, as we show in Appendix A.6.

The model also generates a prediction on how marriage payments should vary with aggregate income.

Proposition 5. *Marriage payments in the first period τ_1^* are lower when aggregate income y_1 is lower.*

Proof. See Appendix A. □

Figure 1 illustrate how equilibrium forces generates the last two propositions.

In sum, this model shows that the direction of marriage payments is likely to play a crucial role in determining how aggregate income shocks affect the probability of child marriage. In particular, in this model, it is the same mechanism (i.e. virilocality) which generates this type of asymmetry: we do not need to invoke any other systematic difference between contexts to generate the main theoretical predictions.

2.4 Extensions

In this subsection, we briefly describe the outcome of two extensions to the model, which are examined in greater detail in Appendix A.

First, we consider how heterogeneity in a woman's household composition during youth can generate heterogeneity in the response of age of marriage to negative income shocks. As described in Appendix subsection A.7, the presence of siblings, and particularly of brothers, appears to attenuate the effect of a reduction in aggregate income as long as sons provide substantial income to their parents' household.

Second, we also consider male-biased sex ratios in dowry societies, as frequent in India (Appendix subsection A.8). When there are fewer women than men in the marriage market, and hence the sex ratios are imbalanced, the negative effect of droughts on child marriage is stronger than when the sex ratios are balanced.

3 Data and descriptive statistics

In this section, we describe the sources of data that we exploit to test the main predictions of our model in Sub-Saharan Africa and in India. All datasets used in the analysis are summarized in Appendix table A3.

3.1 Marriage data

Our main data source are the Demographic and Health Surveys (DHS). DHS are nationally-representative, household-level surveys carried out in developing countries around the world. For Sub-Saharan Africa, we assembled all the publicly-available DHS between 1994 and 2013 where geocoded data are available, resulting in a total of 73 surveys across 31 countries.[14] In the DHS, GPS data consist of the geographical coordinates of each DHS cluster (group of villages or urban neighborhoods) in the sample and are crucial for our analysis to identify respondents exposed to local rainfall shocks.[15] The list of African countries and survey waves included in the analysis is reported in the Appendix table A4. For India, we use the DHS collected in 1998 for a direct comparison with the DHS Sub-Saharan Africa sample. In addition, to span a larger time horizon and to exploit useful information about marriage migration, we check that our results are robust to the inclusion of the India Human Development Survey (IHDS) from 2004-05.[16]

Across all the surveys, the information on a woman's age at first marriage is collected ret-

[14] In addition to the 30 countries with publicly available data, we requested access to the restricted DHS survey from Eritrea.

[15] Measurement error up to 5km is added to geo-coordinates to ensure respondent confidentiality, as described here: https://dhsprogram.com/What-We-Do/GPS-Data-Collection.cfm (last accessed Jan 31, 2019).

[16] The DHS India surveys are also referred to as the National Family Health Surveys (NFHS). There are two additional DHS surveys available for India: one conducted in 1992, and one conducted in 2005, but they do not provide information on women's district of residence: this is why we complement our Indian data with the IHDS instead. The IHDS is a nationally-representative, household-level survey first carried out in 2004-05. A second wave was held in 2011-12, but it features primarily panel information on the married women who were already interviewed in the previous wave, and hence does not add a significant number of observations to the 2005 sample. The two Indian surveys do not contain GPS coordinate information; instead, they provide information on each woman's district of residence, which we can use to match each observation to the history of weather shocks.

rospectively during the woman's interview: women are asked to recall the age, month and year when they were first married.[17] The main difference across the surveys is the universe of women that is sampled for the interview. In the Africa DHS, all women in the household between the ages of 15 and 49 are interviewed. In contrast, in the India DHS, all ever-married women aged 15-49 in the household are interviewed.[18] In order to ensure comparability across surveys and avoid excluding never-married women in the sample from Sub-Saharan Africa, we limit our analysis to women who are at least 25 years old at the time of the interview. By this age, most women are married (87% in our African sample). To look at comparable cohorts across the two sets of surveys, we focus on women born between 1950 and 1989.

Prior empirical evidence has indicated that civil conflict is associated with delayed marriage and lower female empowerment in the household (Jayaraman, Gebreselassie, and Chandrasekhar, 2009; La Mattina, 2017). More generally, if conflict changes virilocality practices and affects the availability of men in the marriage market, our theoretical framework would no longer be a suitable representation of the environment, and hence our propositions may be less likely to hold. For these reasons, we expect that marriage markets will be significantly affected by the intensity of civil conflicts in Sub-Saharan Africa. Hence, we exclude women exposed to major civil conflicts between ages 12 and 17. To identify the onset and the end of the main conflicts in Sub-Saharan Africa in our sample period, we use data from UCDP/PRIO Armed Conflict Dataset, as detailed in Appendix table A5.

As reported in table A2 Panel A, our final sample consists of 326,645 women in Sub-Saharan Africa, and 66,466 women in India. Figure A3 plots the distribution of ages of marriage in our data. We consider women who marry from age 12 onwards. Indeed, only few marriages are recorded before the age of 12 years. In both regions, the hazard into child marriage is relatively low up until age 13 or 14, which is consistent with the hypothesis that girls are often considered ready for marriage at the onset of puberty, that usually occurs sometime in the early teenage years (Field and Ambrus, 2008). The mean age at first marriage is low, 18.7 years in Africa and 17.6 years in India, and a significant fraction of women are marrying before age 18 (46.7% and 53.9% in Africa and India, respectively).

[17] The exact questions are: "Are you currently/Have you ever been married or lived together with a man as if married?", "In what month and year did you start living with your husband/partner?" or "Now I would like to ask about when you started living with your first husband/partner. In what month and year was that?" and "How old were you when you first started living with him?". Note that the India DHS do not elicit information on the month of first marriage.

[18] In the IHDS, only one ever-married woman aged 15-49 is interviewed in each household.

3.2 Weather data and construction of weather shocks

To examine how aggregate economic conditions affect the child marriage hazard for young women, we follow an approach that is widely used in the economics literature, exploiting variation in local rainfall as a proxy for local economic conditions (see Jayachandran (2006); Burke, Gong, and Jones (2015); Kaur (forthcoming); Shah and Steinberg (2017) among many others). The appeal of this approach is that rainfall is an exogenous event that has meaningful effects on economic productivity in both Africa and India, where rural households rely heavily on rain-fed agriculture for their economic livelihood. Droughts, in particular, tend to suppress agricultural output, which has deleterious effects on households' incomes.

To construct a measure of local droughts, we use rainfall data produced by geographers at the University of Delaware ("UDel data"). The UDel dataset provides estimates of monthly precipitation on a 0.5 x 0.5 degree grid covering terrestrial areas across the globe, for the 1900-2010 period.[19] For Africa, we use the GPS information in the DHS data to match each DHS cluster to the weather grid cell and calculate rainfall shocks at the grid cell level. Our main sample matches up to 3,180 unique grid cells across 31 countries in the Sub-Saharan African region, each of which is approximately 2,500 square km in area. For India, the lack of GPS coordinate information prevents us from using the same approach. Instead, we use a mapping software to intersect the UDel weather grid with a district map for India, and then calculate land-area weighted average rainfall estimates for each district. Of the 675 districts in India, 440 in 26 states are represented in our main sample, and these districts have a mean area of over 5,000 square km.

The existing economic literature implements a wide variety of methodologies to construct measures of relative rainfall shocks. Here, we adapt an approach used by Burke, Gong, and Jones (2015) and define a drought as calendar year rainfall below the 15th percentile of a location's (grid cell or district) long-run rainfall distribution. We use a long-run time series (1950-2010) of rainfall observations to fit a gamma distribution of calendar year rainfall for each location. We then use the estimated gamma distribution for a particular location to assign each calendar year rainfall realization to its corresponding percentile in the distribution. We also explore robustness

[19] 0.5 degrees is equivalent to about 50 km at the equator. The rainfall estimates in the UDel data are based on climatologically-aided interpolation of available weather station information and are widely relied upon in the existing economic literature (see for example Dell, Jones, and Olken 2012; Burke, Gong, and Jones 2015). For a detailed overview of the UDel data and other global weather data sets, see Dell, Jones, and Olken 2013.

to a rich set of alternative definitions of rainfall shocks.

This measure of rainfall is particularly appealing given the requirements of our research design. First, as we document in the next subsection, our drought measure has a sizable impact on local crop yields. Second, this measure of drought is orthogonal to permanent local characteristics which are likely to influence the timing of marriage, such as the economic development of an area and the economic opportunities available to women (e.g. access to schooling, labor market condition, etc.). By defining the shock at a given location as calendar year rainfall below the 15th percentile of that location's historical rainfall distribution, all locations have the same probability to experience a shock in any given year. Thus, by construction, this measure of shock should be orthogonal to unobserved local characteristics. Although each location is equally likely to have experienced a shock in any given year, rainfall in a given location varies over time, so our identifying variation comes from the random timing of the shocks.

In Appendix figure A1 we plot the percentage of grid cells (for Sub-Saharan Africa) and districts (for India) exposed to drought in each calendar year. Given that droughts are defined as a variation in rainfall below the 15th percentile, the average probability of experiencing a shock in each region is close to 15%. Most importantly, figure A1 provides evidence that our rainfall shock measures are orthogonal to long-run rainfall trends, thus limiting the concern of a spurious relationship driving our results.

3.3 Weather shocks, crop yields, and household resources

The relationship between weather shocks and agricultural output is well established in the literature. In this subsection, we explore how the specific measure of rainfall shocks we constructed affects aggregate crop yields in Sub-Saharan Africa and India. To do so, we combine the rainfall data with yield data, which are available annually for each country in Sub-Saharan Africa over the period 1960-2010 from the FAOStat and for each district in India over the 1957-1987 period from the World Bank India Agriculture and Climate Data Set. We use data on GDP per capita and aggregate household consumption for Sub-Saharan African countries from the World Bank between 1961 and 2010. For India, we use aggregate state-level data on net state domestic product (NSDP) between 1961 and 1989 and microdata on household consumption aggregated at the district level from the National Social Survey (NSS) between 1994 and 1998.[20] Because

[20] District identifiers are not available in the NSS before 1994, but we verify robustness in the state-level aggregation.

monsoons in India take place in the second half of the year, we consider income and consumption happening in the year following the rainfall realization.

For Sub-Saharan Africa, we estimate the impact of drought on the natural logarithm of yields of the five main staple crops growing in the continent: maize, sorghum, millet, rice, and wheat. We also consider per capita GDP and household consumption. Since only country-level data is available, we construct measures of country-level droughts in the same manner as in the main analysis. All the estimates include year and country fixed effects, so the impact of droughts is identified from between-countries and between-years variation in rainfall. As shown in table 1, droughts reduce maize, rice, wheat, sorghum and millet yields. Moreover, droughts reduce average cereals yields by 12% (column 6, $p < 0.01$), per-capita GDP by 5% (column 7, $p < 0.10$) and aggregate household consumption by 7% (column 8, $p < 0.05$).

Similarly, for India, we rely on crop yield data from the World Bank between 1957 and 1987, which has the advantage of providing crop yields at the district level. We look at the impact of rainfall shocks (constructed at the district-level) on the natural logarithm of the yields of five most important crops in the country (rice, wheat, jowar, maize and bajra). As reported in table 2, droughts negatively and strongly affects yields of all the major crops cultivated in India. On average, drought reduces average crop yields by 16% (column 6, $p < 0.01$), net state domestic product by 4% (column 7, $p < 0.01$), and household consumption by 2% (column 8, $p < 0.10$).

These findings are further supported by the evidence provided in Appendix figure A2, where we plot the coefficients of dummies for each vingtile of the rainfall realization on the natural logarithm of crop yields, to explore the relationship between shocks and yields across the distribution of rainfall realizations. In Sub-Saharan Africa, lower rainfall is clearly associated with lower agricultural output, but we do not observe a clear positive relationship between higher rainfall realization and crop yields, at least with the type of geographical variation that we are exploiting (panel a). Similar patterns are found for crop yields in India, where we document a consistently positive correlation between rainfall and yields for low levels of rain, and a less clear correlation for higher levels (panel b). The notable exception is rice, for which a higher level of rainfall realization is positively associated with yield (panel c).

Overall, the evidence provided in this subsection confirms that our constructed measure of drought strongly reduces agricultural output, income and consumption in both Sub-Saharan Africa and in India over our sample period, making it a useful proxy for adverse income shocks in both regions.

4 Empirical strategy

To examine the impact of weather shocks on the timing of marriage and on the hazard into child marriage, we estimate a simple discrete approximation of a duration model, adapted from Currie and Neidell (2005). Below, we discuss our baseline specification. We also present additional specifications to study the characteristics of the marriages that occur during droughts and the long-term effects of rainfall shocks on age of marriage and fertility. Finally, we discuss the main potential threats to our identification strategy.

4.1 Main specification

The duration of interest is the time between t_0, the age when a woman is first at risk of getting married, and t_m, the age when she enters her first marriage. In our analysis, t_0 is age 12, which is the minimum age at which a non-negligible number of women in our sample report getting married for the first time.

We convert our data into person-year panel format. Hence, a woman who is married at age t_m contributes ($t_m - t_0 + 1$) observations to the sample: one observation for each at-risk year until she is married, after which she exits the data. We merge these individual data with our rainfall data at the year level. In Sub-Saharan Africa, where there is typically one rainy season in the first half of the year and one in the second half, and where marriages occur rather uniformly throughout the year according to DHS data, we consider the calendar year in which a woman is age t. In India, where 70% of marriages in our IHDS data occur in the first half of the year, and where the monsoon and post-monsoon seasons are in the second half of the year, we consider rainfall in the year preceding the one in which the woman turns age t, consistent with our evidence on the effects of rainfall on income and consumption in the region.

Table A2 shows descriptive statistics for the person-year merged sample used in the analysis. Using this sample, we estimate the probability of marriage of woman i living in location g (grid cell in Sub-Saharan Africa, district in India) born in cohort k and entering her first marriage at age t as follows

$$M_{i,g,k,t} = X_{g,k,t}\beta + \alpha_t + \omega_g + \gamma_k + \epsilon_{i,g,k,t}. \quad (1)$$

The dependent variable, $M_{i,g,k,t}$ is a binary variable coded as 1 in the year the woman gets married, and zero otherwise. Since we are interested in child marriage, we examine data on women till age 24 or 17, depending on the specification. Thus, women married after age 24, or 17, are right censored.[21] The variable $X_{g,k,t}$ is a time-varying measure of weather conditions in location g during the year in which the woman born in year k is age t. Specifically, included in $X_{g,k,t}$ is a dummy indicator for a drought occurring in a given year. β is the main coefficient of interest and measures the effect of rainfall shocks on the probability of marriage. α_t is a vector of age fixed effects, which controls for the fact that marriage has a different probability to occur at different ages. We include location-specific fixed effects, ω_g, to control for time-invariant local unobservable characteristics, such as geographic, economic and cultural factors, and year-of-birth fixed effects γ_k to account for cohort effects. Since we are combining data across multiple countries, we use population-weighted survey weights to make the results representative of the countries included in the analysis. We estimate regressions with standard errors clustered at the grid-cell (for Sub-Saharan Africa) or district (for India) level, to allow for serial correlation in the error terms across women in the same area, and show robustness to clustering at larger geographic units.

With the inclusion of location (grid cell or district) and year of birth fixed effects, the impact of weather shocks on the child marriage hazard is identified from within-location and within-year-of-birth variation in weather shocks and marriage outcomes. The key identifying assumption of the analysis is that, within a given location and year of birth, the weather shocks included in $X_{g,k,t}$ are orthogonal to potential confounders. The exogeneity of rainfall shocks is particularly important in our setting because, given the retrospective nature of our analysis, there are many unobservables for which we cannot control. Most importantly, we lack data on parental wealth or poverty status around the time of a woman's marriage, on the educational background of her parents, and on the numbers and ages of her siblings, all of which will affect the marital timing decisions (Vogl, 2013).

To control for cohort-specific changes in marriage behavior at the country (Sub-Saharan Africa) or state (India) level, such as a change in the legal age at marriage, we include an additional specification that controls for country or state fixed effects interacted with ten-year

[21] For example, a woman who is married at age 16 would appear five times in the regression for child marriage, and her marriage vector would be $\{M_{i,g,k,12}, ..., M_{i,g,k,15}, M_{i,g,k,16}\} = \{0, ..., 0, 1\}$. A woman who is not married by age 18 appears in the data six times, and her marriage vector is a string of zeroes.

birth cohort fixed effects.

4.2 Threats to identification

A potential threat to our identification strategy comes from the fact that we are considering weather shocks in the respondent's location at the time of the survey rather than at the time of marriage. Unfortunately, the DHS (and the IHDS) elicit information on where a women currently resides, but not on where she resided around the time of her first marriage. This data limitation may introduce error in our measure of rainfall shocks if the respondent's recorded place of residence is different, and sufficiently far, from her location at the time of marriage. This can happen for two main reasons. The first one relates to the custom of virilocality. In India and in many parts of Africa, a daughter joins the household of the groom and his family at the time of marriage. Thus, the village they live in at the time of the survey may differ from the one where they grew up in.[22] The second reason is due to the possibility that the respondent and her family may simply migrate after marriage but before the survey takes place.

While virilocality is common in both regions, the available data on marriage migration indicates that most married women do not move far from their natal home. Table A6 in the Appendix reports migration pattern for the set of African countries in our analysis and for India. Panel A, column 1, shows that more than 77% of women do not move at the time of marriage in Sub-Saharan Africa. Furthermore, when migration does occur, previous literature suggests that it happens across relatively short distances. Mbaye and Wagner (2013) collect data in Senegal and find that married women live an average of 20 km from their natal home. Unfortunately, information on the distance from natal home to the current location is not available in the DHS.

In India, marriage migration is more common: 58.02% of women migrated at the time of marriage. Again, though, migration happens at a relative close distance or likely within the geographic area at which we define our rainfall shocks. By exploiting information in the IHDS, we found that the median travel time between a married woman's current residence and her

[22] In their seminal paper on marriage migration, Rosenzweig and Stark (1989) argue that marrying a daughter to a man in a distant village reduces the co-movement of parental household income and daughter's household income, which facilitates making inter-household transfers in times of need. This interpretation has been questioned in a recent work by Fulford (2013), who shows that inter-household transfers from daughters to parents are virtually non-existent in India, and that households in areas with high rainfall volatility do not send daughters to more distant villages, as might be expected under the theory.

natal home is 2 hours at the median and less than 6 hours for 90% of the respondents (see table A6, panel B). To better understand migration patterns in India, we also look at empirical evidence coming from previous literature. In ICRISAT, the average distance between a woman's current place of residence and her natal home is 30 km (Rosenzweig and Stark, 1989). In the 1983 and the 1987-88 NSS, only 6.1% of households are classified as "migrant households", those for which the enumeration village differs from the respondent's last usual residence Atkin (2016).

While marriage migration over vast geographic areas does not appear to be a major threat in our contexts, another potential concern for our identification strategy is whether marriage migration may happen differentially during a drought. For example, if women who are getting married are more likely to migrate to an area exposed to a drought, we would expect a positive correlation between marriage probability and droughts. On the contrary, if women are less likely to migrate to a drought area at marriage, we would expect a negative correlation between marriage probability and droughts to arise spuriously. To examine whether either of these scenarios is likely to occur, we estimate the relationship between the occurrence of a drought at the time of marriage in the place of current residence and a set of marriage migrations outcomes from the DHS and the IHDS. In Sub-Saharan Africa, women do not appear less likely to have remained in their village of birth (table A7, column 1), nor to have migrated for marriage during a drought (column 2). In India, we do not find that drought affect marriage migration, nor distance from the village of origin (table A7, columns 3-5).

Taken together, the available information on marriage migration in Africa and India suggests that most of the women who move away from their natal home at the time of marriage are not likely to be migrating out of the geographic areas over which we measure the rainfall shocks. In addition, they do not appear to change their migration patterns or destination in response to droughts. Hence, marriage migration is unlikely to significantly bias our estimates.

A final potential threat to our empirical strategy comes from measurement error in women's recollections of the age and year of marriage. Errors in women's recollections will lead to greater imprecision in our estimates. Overall, validation studies of age variables in the DHS have suggested that such measures are rather accurate (Pullum, 2006), limiting concerns about the effect of measurement error.

5 Empirical results

Our main results examine the effect of droughts on the timing of marriage and particularly on the hazard into child marriage in Sub-Saharan Africa and in India.

5.1 Main results: effect of rainfall shocks on the timing of marriage and on child marriage

Table 3 reports our first set of results: the effect of adverse rainfall shocks on the timing of marriage for young women aged 12 to 24. We report the estimated coefficients for equation 1 separately for the Sub-Saharan African countries in our sample (columns 1-3) and for India (columns 4-5). Consistent with our theoretical model, we find that adverse rainfall shocks have opposite effects on the timing of marriage in the two regions: in Sub-Saharan Africa, droughts increase the probability of child marriage while in India droughts decrease it. In Africa, women who experience a drought between ages 12 and 24 are 0.37 percentage points (pp) more likely to get married in the same year (columns 1-2, $p < 0.01$). The average annual marriage hazard for this age group is equal to 0.113, and hence the effect corresponds approximately to a 3.3% increase. All specifications for the Sub-Saharan Africa sample include grid cell fixed effects and those for India include district fixed effects. Even after controlling for fixed effects for each country-by-cohort of birth combination, we find that the effect of a drought is equal to 3.2pp (column 3, $p < 0.01$).[23] In line with the predictions of our model, income shocks have an opposite effect on Indian women. In India, women who experience a drought between ages 12 and 24 are 0.41pp *less* likely to get married in a given year (column 4, $p < 0.01$). Given a mean of the dependent variable of 0.145, this effect corresponds approximately to a 2.8% decline. Including fixed effects for the interaction between states dummies and cohort dummies further decreases the coefficient to -0.44pp (column 5, $p < 0.01$).

In figure 3, we explore the heterogeneity of this effect by the woman's age by interacting drought with each age dummy. Consistent with our model, the effects are concentrated in early years, and particularly among child marriages (before the age of 18) in both countries. In Sub-Saharan Africa, the strongest effects are observed between ages 15 and 18 and at age 21, with no effects at later ages (panel a). In India, the effects are concentrated between ages 14 and 16

[23] Cohorts dummies are defined as ten-years intervals in the year of marriage (1950-1959, 1960-1969, 1970-1979, 1980-1989).

only (panel b).

Hence, in table 4, we focus on child marriage, our main outcome variable. We restrict the life-cycle horizon between ages 12 and 17 and find that, in line with what was reported above, droughts have opposite effects on the hazard into marriage at these early ages in the two regions. In Sub-Saharan Africa, girls who experience a drought between ages 12 and 17 are 0.2-0.26pp more likely to get married in the same year (columns 1-2, $p < 0.05$ and column 3, $p < 0.10$). The average annual marriage hazard for this age group is equal to 0.088, and hence the effect corresponds to a 2.3%-3% increase in the annual hazard of child marriage. In India, women who experience a drought between ages 12 and 17 are 0.46-0.47pp less likely to get married in that same year (columns 4-5, $p < 0.01$). Given a mean of the dependent variable of 0.109, this effect corresponds to a 4.2-4.3% decline in the annual hazard of child marriage.

In section 6, we extensively analyze the robustness of these findings to alternative choices of the sample and of the main independent variable.

5.2 Effects of rainfall shocks on fertility

A dramatic consequence of child marriage is early fertility, which is arguably one of the most important risks facing teenage girls in developing countries, especially in Sub-Saharan Africa (Duflo, Dupas, and Kremer, 2015). In addition to its socioeconomic consequences, pregnancy in adolescence is associated with increased risks of maternal and fetal complications, including premature delivery, and with worse health and socioeconomic outcomes for the next generation (Chari, Heath, Maertens, and Fatima, 2017). In our sample from Sub-Saharan Africa and India, 32% and 31.5% of women respectively have their first child before turning 18. Documenting an effect of weather shocks on the timing of fertility is also important to show that our main findings are likely to have long-term consequences on women's lives, and possibly on those of their children.

We study the effect of droughts on the onset of fertility, substituting marriage with birth as the outcome variable in equation 1. Of course, age of marriage is only one of the many channels through which an income shock can affect fertility. For example, women may choose to avoid having children during times of hardship, generating procyclical fertility patterns (Chatterjee and Vogl, 2018) or, on the contrary, to take advantage of times when the marginal product of their labor is lower to have children (Pitt and Sigle, 1998). Yet, the differential patterns we document across countries within Sub-Saharan Africa are consistent with the hypothesis that changes the timing of marriage may generate a shift in the timing of first birth and, particularly in Sub-Saharan Africa, in overall fertility rates.

When we replace the marriage outcome variable with a variable that takes value 1 when a woman has her first child, we find that in Sub-Saharan Africa a drought increases the annual hazard of early fertility by 0.18-0.22 percentage points (table 7, columns 1-3, $p < 0.05$), which corresponds to a 4-3.5% increase relative to a mean dependent variable of 0.055. We find no effects of rainfall shocks on the timing of fertility in India.[24]

In Appendix C, we document a potential long-term effect of this fertility shift: in Sub-Saharan Africa, but not in India, a history of droughts in a woman's teenage years is positively related to child marriage and to total fertility at age 25 (Appendix table A10). In the same Appendix, we also examine how the relationship between droughts and educational investments differs in our two regions of analysis. Interestingly, we find that droughts increase the hazard of school dropout to a similar extent between ages 6 and 11 in SSA and India. Between ages 12 and 17, droughts have a stronger negative effect in SSA than for earlier ages, but have no effect in India, where delayed marriage could attenuate the negative effects of droughts on educational investments.

6 Robustness checks

In this subsection, we perform a wide array of checks and additional tests on our data, to verify the robustness of our main results.

6.1 Robustness to alternative definitions of rainfall shocks

As a first robustness check to our main results, we study how the impact of drought varies with the definition of our drought measure. We use three approaches. First, we re-estimate our main regression equation varying cutoff levels to define a drought, ranging from the 5th percentile to the 45th percentile. Figure A4 plots the estimated coefficients for different cutoff percentiles for drought, along with 95% confidence intervals. In both regions, the point estimate is fairly stable

[24] In Appendix table A9, we examine these effects extending the age range up to age 24. In this sample, the effect of drought on the timing of first fertility ranges from 0.34 to 0.30pp in Sub-Saharan Africa (columns 1-3, $p < 0.01$).

around the default 15th percentile cutoff, and as the definition of drought becomes more severe, the estimated impact increases in absolute value.

Second, in table A14 we examine the association between the level of rainfall and the hazard into child marriage, following our usual specification. We find that an increase in annual rain by 1 meter is associated with a decline in the child marriage hazard by 0.35-0.46 percentage points in Sub-Saharan Africa (columns 1-2, $p < 0.05$, not significant at conventional levels in column 3), and with an increase in such a hazard by 0.39-0.41pp in India (columns 4-5, $p < 0.10$).

We know from figure A2 that high level of rain have ambiguous effects on agricultural output, particularly for rice. To further investigate the relationship between high level of rainfall and child marriage, we add a variable that captures floods to our main specification, defined as rainfall realizations that exceed the 85th percentile of rain. We find that floods have no discernible effect on the child marriage hazard in Sub-Saharan Africa (Appendix table A15, columns 1 and 2) but reduce the child marriage hazard in the India DHS sample (column 3, $p < 0.01$). As expected, though, the negative effect of floods is concentrated in regions that do not cultivate rice: when the percentage of land cultivated as rice is added to the regression and interacted with flood, the interaction has a positive sign which exceeds the absolute value of the main effect of flood (column 4, $p < 0.05$).

Third, we estimate our main regression equation with indicators for the bottom rainfall quintiles between 1950 and 2010. Effects are comparable to our measure of drought in India, but weaker in Sub-Saharan Africa, as expected given that effects fade out substantially after the 15th percentile in figure A4 (see Appendix table A16, column 1 $p < 0.10$ and column 2 $p < 0.01$).

Last, we consider the time structure of the effect of droughts, by examining lagged and future shocks. In our model, without credit markets and with no serial correlation in the shocks, only contemporaneous droughts affect behavior. When households can save or when shocks are correlated over time, one may expect past shocks to matter for the current child marriage hazard as well. Indeed, when we examine Sub-Saharan Africa, we find that past and future shocks have no effect on the marriage hazard (Appendix table A17, columns 1-3). In India, past shocks have a smaller but sizable effect on the marriage hazard relative to contemporaneous shocks, while future shock does not appear to matter, reassuringly (columns 4-6).[25] In columns 7 and 8, we

[25] Measurement error in the age of marriage or in the exact timing of the shock could in principle lead future shocks to also matter. However, this is not the case in our analysis.

ignore the timing of the rainy seasons in the two regions and consider the prior year droughts in Africa (as we do for India in the rest of the paper) and the current year droughts in India (as we do for Africa in the rest of the paper), respectively. In either specifications, in agreement with our income and consumption estimates, we find no effects of droughts on the timing of marriage.

6.2 Inference: clustering at larger geographic units

To account for the potential correlation in error terms across space between different grid cells in Sub-Saharan Africa and districts in India, we consider clustering our standard errors at the country level and at the state level, respectively. To account for the small number of Indian states in our sample, we also compute wild bootstrapped p-values following Cameron, Gelbach, and Miller (2008). In table A26, we replicate the estimates from table 4 and report the corresponding p-values under the different clustering assumptions. We observe only small changes in p-values after the clustering at much larger geographic units, which do not affect the statistical significance of our estimates.

6.3 Robustness checks for the Sub-Saharan African sample

As an additional robustness check, we verify that our Sub-Saharan Africa findings persist when we do not use population-weighted sampling weights (table A18 column 1, $p < 0.05$), when we use the most recent wave of data for each country (column 2, $p < 0.05$) and when we focus on the subsample of ever-married women, which is more directly comparable to the India DHS (column 3, $p < 0.05$).

We also examine how droughts affect the timing of marriage and child marriage during periods of intense civil conflict, which are otherwise excluded from our analysis. Several reasons lead to hypothesize that our main hypotheses would not carry through during conflicts: sons may be unable to support their parents and there may be few marriageable men available in the marriage market. Indeed, as reported in table A19, we find that droughts have a negative impact on the timing of marriage (columns 1 and 2) and on child marriage (columns 3 and 4). Pooling the conflict data with our main data, we find that our findings on the timing of marriage are still robust to the inclusion of observations affected by violent conflict (column 1), but not the findings on child marriage, which are substantially attenuated (column 3).

6.4 Robustness checks for the Indian sample

To study whether our findings continue to appear in later datasets from India, which span a time period closer to that of the DHS from Sub-Saharan Africa, we examine the impact of droughts in the 2004-2005 IHDS. In the IHDS data, droughts reduce the child marriage hazard by 0.85 percentage points (Appendix table A20 columns 3 and 4, $p < 0.01$). When we pool together the DHS and the IHDS, adjusting sampling weights for population, we find that droughts reduce the child marriage hazard by 0.97-1pp (columns 5 and 6, $p < 0.01$).

7 Mechanisms: heterogeneity analysis and effects on prices

In this section, we study whether the mechanisms underlying our results are consistent with our model, within each context, and hence whether child marriage, when marriage payments prevails, is a source of consumption smoothing. We do so by examining heterogeneity in the effect of droughts across multiple margins.

In Appendix D, we also examine the characteristics of couples that form during droughts. We find that it is the low-educated women in SSA and the high-educated ones in India who seem more likely to marry. Consistent with our model, we don't find any statistically significant difference in terms of likelihood of marriage migration, age gaps and husband's education either in Sub-Saharan Africa nor in India.

7.1 Heterogeneity of the effects by mode of marriage payment tradition

In our model, the marriage payments that prevail in Sub-Saharan Africa and India can generate incentives for parents to time their children's marriage as a consumption smoothing mechanism in opposite way in response to negative aggregate shocks. In this section, we examine whether such an hypothesis can account for the effects of droughts that we have documented above, by exploiting heterogeneity between and within countries in our sample.

7.1.1 Heterogenous effects within SSA

Within Sub-Saharan Africa, we begin by exploiting historical heterogeneity in marriage payments across ethnic groups across different countries. Our data source for measuring traditional marriage customs in different ethnic groups is the University of Zurich's *Atlas of Pre-Colonial Societies* (ATLAS). The ATLAS provides historical information on transfers made at marriage, either bride price or dowry, for a large set of ethnic groups identified in the ethnography literature. It is an extension of Murdock's *Ethnographic Atlas* (1957), which has been extensively used in the literature, often in combination with the DHS (see Alesina, Giuliano, and Nunn 2013 and Michalopoulos, Putterman, and Weil 2016 among others). For each ethnic group, the Atlas provides information about the *mode of marriage*, which is the traditional marriage payment practice. We use information from the ATLAS on the size of each ethnic group in a given country to construct a measure of the prevalence of the bride price tradition within each country in our sample, as reported in Appendix Table A1.[26] Figure 2 clearly shows across-countries variation in marriage payments custom in the countries in our sample. In our data, the countries where less than 50% of the population belongs to ethnic groups that traditionally practice bride price include are Eritrea, Madagascar, Malawi, Mozambique and Zambia.

By using historical information on marriage payments at the country level, rather than actual payments, we circumvent a fundamental empirical challenge. First of all, information on actual bride price payments is unfortunately not available in the DHS nor in any cross-country source of data for Sub-Saharan Africa. Second, bride price payments are endogenous to the economic circumstances at the time of marriage, as shown in our model. We hence follow existing literature (Ashraf, Bau, Nunn, and Voena (forthcoming), for instance), that has shown that historical mode of marriage has strong predictive value with respect to modern practices, and use historical practices as a predictor of modern ones.

In table 5, we report the estimated effects of rainfall shocks in Sub-Saharan Africa exploiting heterogeneity in bride price prevalence across countries. Columns 1 and 2 show the effect of drought on child marriage for the subsample of Sub-Saharan Africa countries where the bride price custom is the prevailing norm (BP$\geq$ 50%). We find that droughts have a strong effect on the child marriage hazard: during a drought, the annual hazard into child marriage increases by 0.26pp or 3% (columns 1-2, $p < 0.05$). On the contrary, no statistically significant association between adverse rainfall shocks and child marriage emerge in countries with a bride price prevalence lower than 50% (columns 3-4). Hence, in areas where bride price is the historically prevalent historical mode of payment at the time of marriage, households hit by negative income

[26]The ATLAS is available at http://www.worlddevelopment.uzh.ch/en/atlas.html (last accessed August 13, 2018).

shocks encourage their daughters to marry before they reach adulthood, while on average there does not appear to be a relationship between aggregate income fluctuations and the timing of marriage in countries where bride price is not customary among the majority of the population.

To dig deeper into the role played by marriage payments in shaping early marriage's decision, we next test our main effect in Eritrea. According to the ATLAS, the Tigrigna people of central Eritrea – the largest ethnic group in the country, originating from Egypt – is the only ethnic group to engage in dowry payments within Sub-Saharan Africa. Several sources report that dowry is now widespread throughout the country, even though multiple norms coexist (Tronvoll, 1998; Gebremedhin, 2002; Favali and Pateman, 2003; Tesfagiorgis, 2010). Hence, we next study the effect of droughts using data from the 2002 Eritrea DHS.[27] According to our model, we should observe a negative relationship between droughts and child marriages in countries where young girls' families have to pay a dowry at marriage: when adverse shocks occur, parents would prefer to wait to marry their daughter. The results reported in column 5 of table 5 confirm this hypothesis: when focusing on Eritrea only, we find that droughts reduce the hazard of child marriage in the same year by 1.2pp (a 14% reduction, $p < 0.10$). This finding further indicates that marriage payments indeed are likely to play a role in marriage's decisions: even within Africa, in the presence of an income shock and in places where dowry is the prevailing mode of payment at marriage, a young girl is less likely to get married when a drought occurs.

To further corroborate our theory, we explore the relationship between traditional marriage payments and the impact of drought on child marriage by exploiting heterogeneity in marriage payments customs within Sub-Saharan Africa countries. To do so, we compile a comprehensive concordance between the ethnic groups reported in the DHS (a variable available for 53 of the 73 surveys) and those featured in the ATLAS. A detailed description of the concordance is featured in Appendix B. In Appendix table A8, we report the coefficients that we obtain for estimating the relationship between droughts and child marriage interacted with a vector of ethnic-level historical characteristics. In addition to including dummies for whether or not a woman belongs to an ethnic group that traditionally engages in bride price payments, we follow previous literature (e.g. Ashraf, Bau, Nunn, and Voena (forthcoming)) and include historical correlates of bride price, such as a prominent female role in agriculture and a matrilineal inheritance rule. Indeed, the effect of drought is concentrated among ethnic groups that engage in bride price payments

[27] The Eritrea DHS is part of a small set of DHS which are not publicly available. We applied for permission to access it, while all other datasets we are using are publicly available.

(columns 1-3), particularly those that do not have a matrilineal rule (column 4), consistent with our model. While droughts appear to have no effect on girls that belong to ethic groups that do not practice bride price, the difference compared to the effects on the bride price ethnic groups is not statistically significant.

7.1.2 Heterogenous effects within India

To identify groups that are less likely to be influenced by drought in India, we explore two hypotheses. First, we consider variation in religion. While in contemporary India, dowry payments are widespread across all regions, castes and ethnic groups (Anukriti, Kwon, and Prakash, 2018), the practice originated in the Hindu community (Goody and Tambiah, 1973), which constitutes 75% of our sample. Hence, non-Hindus are potentially less likely to respond to droughts for they are less likely to make dowry payments. Second, like in SSA, we use information from the ATLAS to identify Indian states where fewer than 50% of the population traditionally engages in dowry payments. Unlike in Africa, this measure has not been validated with contemporary data on dowry payments within India and is likely to be a less strong predictor of actual behavior, given how the practice has spread throughout the country.

In table 6, we report the results of augmenting equation 1 with the interaction between drought and a dummy variable equal to 1 if woman i reported a religion other than Hinduism and 0 otherwise (column 1). We then include a specification with the interaction between drought and a dummy variable equal to 1 if woman i lives in a state with fewer than 50% of the population traditionally practicing dowry and 0 otherwise (column 2). Last, to identify a group of likely low responders, we include a specification with the interaction between drought and a dummy variable that takes value 1 if woman i reports a religion other than Hinduism *and* lives in a state with fewer than 50% of the population traditionally practices dowry and 0 otherwise (column 3). In all specifications, we include a full set of interactions between the above-described dummies with age and birth year fixed effects. We find that effects are concentrated among Hindus, as expected, but we cannot rule out that the effects on Hindus and non-Hindus is statistically identical. Yet, non-Hindus who live in states with low historical prevalence of dowry according to the ATLAS show no response to droughts, and the effect on this subgroup is statistically significantly different from the one estimated on the rest of the sample ($p < 0.10$).

Next, we explore geographic heterogeneity over time between the rest of the country and

South India, where historically dowry was not practiced, but, according to the literature, was adopted over the course of the twentieth century. Importantly, we expect that the effect of droughts would be muted for the earlier cohorts, but present for the more recent ones, as long as it is indeed the practice of dowry, and not other historical fundamentals, that govern the relationship between droughts and age of marriage in this region.[28] We find that on average, in South India, the effect of droughts is similar to that in the rest of the country (table 6, column 4). However, for the earliest cohorts in our sample, born before 1960, we observe a *positive* effect of droughts on the hazard of marriage (column 5, $p < 0.01$), which, as expected, turns negative for later cohorts.

Overall the results in tables 5, A8 and 6 suggest that marriage payments in different contexts can generate an opposite effect of how an economic shock affects households' decisions on child marriage, while there does not appear to be any effect of droughts on child marriage where marriage payments are not customary.

7.2 Heterogeneity by the impact of rainfall shocks on income and consumption

In our model, child marriage is a coping mechanism for households affected by an income shock. Empirically, we have used droughts as a source of variation in the resources available to a household. Hence, we examine how droughts influence our outcome of interest differently depending on the impact of droughts on agricultural yields (through irrigation), on income (by examining different agro-ecological zones) and on consumption (through credit market development).

7.2.1 Irrigation

First, we examine heterogeneity by the availability of irrigation, using data from the ICRISAT District Level Database of 19 States of India between 1996 and 2011. We construct a dummy variable named *High Irrigation* for states which in a given year are in the top quartile of irrigation, defined as the percentage of cultivated land which is irrigated. We find that the effect of drought is concentrated in states that have low irrigation, and the p-value of the Wald test for equality between *Drought* $\times$ *Low Irrigation* and *Drought* $\times$ *High Irrigation* is $p = 0.047$

[28] For instance, (Srinivasan, 2005) documents a fifteen-fold increase in the real amount of dowries paid in the district of Salem in Tamil Nadu between 1930 and 1970.

(Appendix table A22, column 1).

7.2.2 Agro-ecological zones

Our measure of drought corresponds to a low realization of the local rainfall distribution, and hence represents a different level of rain in different regions. To the extent that local economies can adapt to the rainfall distribution, the effect of these different levels of rainfall may have comparable effects on income. To examine potential heterogeneity in the effect of droughts on income across locations and rainfall distributions, we study how droughts map into income and then into child marriage across agro-ecological zones (AEZs) in Sub-Saharan Africa and in India.[29]

First, we regress log income (either GDP or NSDP per capita) on droughts measured at the SSA country level or at the India state level, interacted with dummies for each AEZ. We find some dispersion in these interactions, but coefficients are almost uniformly negative, with a minimum effect of -13% . Then, we repeat our basic marriage specification allowing for heterogeneity in the impact of droughts by AEZ. Figure 4 reports scatterplots of these two sets of coefficients within each region. As expected, the relationship between droughts, income and child marriage within AEZs have opposite signs in the two regions. That is, in zones in SSA where droughts have the most negative impact on income, droughts also have the most *positive* impact on child marriage. On the contrary, in zones in India where droughts have the most negative impact on income, droughts also have the most *negative* impact on child marriage.

To summarize the relationship between the effect of droughts on income and their effect on child marriage, we fit a linear regression through the coefficients, weighted by the sample size from our marriage data residing in each AEZ. When the effect of droughts on income is 1 pp smaller (i.e. larger in absolute value), the effect of droughts on child marriage is 0.038pp larger in SSA and 0.033pp smaller in India.

[29] To classify AEZs in Africa, we use HarvestChoice's dataset linking geographic grid cells to a 6-category AEZ classification, which can be found at `https://harvestchoice.org/data/aez5_clas` (last accessed January 31, 2019). The categories in this classification are arid, semi-arid, sub-humid, humid, sub-tropical, and tropical highlands. They depend on length of growing period (LGP), temperature, moisture, and elevation. Countries are classified under the AEZ which corresponds to most of their land area. For India, we use the FAO's state-level data on average length of growing period (LGP, downloadable with an FAO account `http://gaez.fao.org`). Since LGP is what defines an AEZ as either arid, semi-arid, sub-humid, or humid in India as well (see definitions `http://www.fao.org/`), we use LGP to classify Indian states by LGP in months, with eight categories ranging from a 2-3 month LGP to a 9-10 month LGP.

7.2.3 Credit market development

Other measures of local development, often correlated with irrigation, can also attenuate the effect of drought on child marriage. One example is the development of the local banking sector, which varies substantially over time and across space in India (Burgess, Pande, and Wong, 2005). We follow Jayachandran (2006) and examine interactions with the number of bank branches per 1000 people between 1960 and 1999, the number of per-capita bank deposits in 1981 and the number of per-capita bank credits in 1981. For each measure separately, we define a state as having *High Banking* equal to 1 if it is in the top quartile of each variable in each year. For all three variables, we find that the effect of droughts are only statistically significant in states that have low development of the banking sector, while no statistically significant effect can be found in the *High Banking* states. However, we cannot rule out that the effects are the same from a statistical viewpoint (columns 2-4, the p-values of the Wald test for equality of the coefficients are $p = 0.363$, $p = 0.362$ and $p = 0.441$).

7.2.4 Household composition

An implication of our model, as discussed in subsection 2.4, is that having siblings, and especially adult brothers, should attenuate a woman's risk of child marriage during droughts, as their earnings can help households smooth the household consumption. This implication of the model can be tested using data from 60 of the 72 waves of the DHS in SSA that provide information about the respondent's brothers and sisters and their ages. No such information is available in the India DHS in 1998.

We examine this hypothesis by augmenting equations to include the interaction of droughts with different measures of household composition that capture the number and the gender of a woman's siblings. One potential caveat of this analysis, of course, is that household composition is correlated with several economic and social factors, including wealth, that are likely to have an independent effect on the timing of marriage and on household's ability to cope with economic shocks.

Table A23 reports the results of considering the effect of droughts on child marriage as a function of a continuous variable that captures the total number of siblings (column 1), of two continuous variables that capture the total number of brothers and sisters (column 2), of two dummies for having a large number (4+) of brothers and sisters (column 3) and, last, of four dummies for having more than one younger or older brother or sister (column 4). All these measures are interacted with the drought dummy and with age and birth year fixed effects. Consistent with our hypothesis, we find that having a large number of brothers significantly attenuates the effects of droughts on child marriage ($p < 0.10$). The effect appears to be driven by older brothers. Interestingly, the only subgroup where the effect of droughts remains significantly positive in the presence of multiple siblings is when the woman only has one or more older sisters, who are likely to be already married and hence to not contribute to their parents' budget constraint when the respondent is at risk of child marriage.

7.3 Heterogeneity by sex ratios in India

Another implication of our model is that the presence of male-biased sex ratios, as are commonly observed in India, should exacerbate the effect of droughts in dowry societies on the timing of marriage. To test this hypothesis, we combine our data with district-level sex ratio data interpolated over time from the Indian Censuses between 1961 and 2001. There are two potentially important caveats in this analysis. First, variation in sex ratio is likely to be correlated with several socioeconomic factors, which could independently attenuate or exacerbate our estimates. Moreover, while sex ratios have been biased for a long time in North India, they are, like dowry, a more recent phenomenon in South India.[30] Second, biased sex ratios increase the relative number of brothers compared to sisters that a respondent may have on average, which would instead attenuate the effects of droughts. Unfortunately, the India DHS does not provide information about the respondent's siblings.

With these limitations in mind, we turn to our empirical analysis. As reported in table A24, a linear function of sex ratios interacted with droughts does not lead to a statistically significant coefficient (column 1 and 2). Consistent with our hypothesis, though, we find that in states with strongly biased sex ratios (fewer than 85 women every 100 men, or 5% of all state-year observations and 12% of district-year observations), droughts have a substantially stronger effect on the timing of marriage compared to states with more balanced ratios ($p < 0.01$, column 3). However, this finding is not robust to using data on sex ratios at the district level is used (column 4), a variation which is arguably more likely to depend on labor market and socioeconomic conditions than the state-level one. Note that droughts continue having a negative effect on

[30] See Borker, Eeckhout, Luke, Minz, Munshi, and Swaminathan (2017) for an interesting hypothesis to explain the coexistence of dowry and biased sex ratios in South India.

the hazard into child marriage where sex ratios are relatively balanced, indicating that it is not the presence of unbalanced sex ratios in India that can explain the difference in the effect of droughts across SSA and India.

7.4 Effects on prices: additional evidence from India and Indonesia

A key implication of our theoretical model is that marriages that occurred during droughts should command lower payments. The decline in the marriage payments, combined with the different price sensitivities of the two sides of the market, generates our equilibrium result on the probability of child marriage. Studying this implication of the model is not possible with the DHS or the IHDS, because neither survey features data on actual marriage payments. More generally, for bride price, no nationally representative dataset from Sub-Saharan Africa is available, to the best of our knowledge.[31] We hence turn to a new dataset for India and to a new context (Indonesia) for bride price.

For dowry in India, we examine an additional data source, the 1998 wave of the Rural Economic and Demographic Survey (REDS), which features information about the dowry paid for the respondents' own marriage and for the marriage of the respondents' daughters. Following Roy (2015), we define as dowry the value of the gross amounts paid at the time of marriage and we express it real terms (2010 Indian Rupees). We use the same variation at the district level that we use in the rest of the paper, with the survey spanning 95 district across 15 states.

For bride price, we turn to Indonesia, a country in Southeast Asia with an ancient bride price tradition, as documented in Ashraf, Bau, Nunn, and Voena (forthcoming). Rich data from the Indonesia Family Life Survey (IFLS) provides information not only on the location of current residence, but also on the location at birth and on migration history. Most importantly, it also collects information on the value of bride price payments (in cash or in kind) that were made for each couple's marriage. We use the 2000 (3rd round) and the 2007 (4th round) waves of the survey. We focus on the province of birth of each female respondent, and merge rainfall data from UDel aggregated at the province level. There are 18 provinces of birth in our sample.

Both the REDS and the IFLS samples are rather small: for the groups we use in the rest of the analysis, we have 5,513 women in the REDS and 11,745 women in the IFLS. Indeed, we

[31] One appealing source, the Kagera Health and Development Survey used in Corno and Voena (2017), only examines one region of Tanzania that represents a single marriage market.

find no significant effects of droughts on the timing on marriage in either of the two samples.[32] However, our model predicts that marriage payments for all child marriages should be lower during droughts, and not only for the marginal marriages. This implication suggests that we may be able to detect effects on marriage payments in relatively small samples. Hence, we move to estimating equation 5 on the REDS and IFLS samples, using the natural logarithm of the marriage payment for child marriages as the dependent variable.

In the REDS data, the mean dowry for the sample of 2,169 child marriages is equal to 80,132 INR, with a standard deviation of 118,223.[33] There is a negative association between dowry paid and marriages occurred during droughts, which are around 17% lower than baseline (table 8, column 1 $p < 0.10$). This finding is indeed highly consistent with proposition 5. However, it is worth emphasizing that such a finding may also be due to a differential selection of women into marriage during droughts. Adding controls for the brides' age of marriage (column 2) and education (column 3) does not substantially change our estimates, suggesting that selection on observables is unlikely to be driving this result.

In the IFLS, the mean bride price for the sample of 1,131 child marriages is equal to 692,544 Indonesian rupees (in real 2005 values), with a standard deviation of 1,589,108. Bride price payments are 45% lower when a drought hits a woman's province of birth. The coefficient is almost unchanged when we include additional controls for the woman's characteristics (table 8, column 4-6, wild-bootstrapped p-values clustered at the province level $p = 0.108$, $p = 0.104$ and $p = 0.092$ respectively).

In sum, data on both dowry and bride price payments shows that these transfers are substantially lower during droughts, in line with the prediction of our model.

8 Conclusions

The findings presented in this paper indicate that in developing countries where marriage payments are customary, the age of marriage responds to short-term changes in aggregate economic conditions in a way that is consistent with simple economic theory. This suggests that there is

[32] We use data from the 1995 Indonesia Intercensal Population Survey (SUPAS) to examine the relationship between droughts and child marriage and find a strong positive effect, as reported in Appendix table A25: a province-level drought increases the annual hazard into child marriage by 1.8-1.9 pp (wild-bootstrapped $p < 0.01$ in column 3 and $p < 0.05$ in column 4) on a sample of 63,903 women.

[33] These numbers and those for Indonesia exclude outliers strictly above the 99th percentile, which are likely to be the result of measurement error.

a potential for economic policy to influence marriage markets, however, in complex ways that interact with culture.

We believe these results can speak to recent evaluations testing the role of cash or in-kind transfers to reduce child marriage around the world: our findings suggest that transfers targeting adolescent girls and their families could have a different effect on marriage and teenage pregnancy depending on the traditional mode of marriage payments in place in different countries and ethnic groups. While transfer programs in sub-Saharan Africa may decrease child marriages, they may have an opposite effect in countries where dowry payments are customary. In line with our results, Baird, McIntosh, and Özler (2011) found that unconditional cash transfers reduce child marriage and teenage childbearing in Malawi but, to the best of our knowledge, there is no rigorous evidence of how unconditional cash transfers can affect marriage in India.[34] In contexts where dowry is prevalent, conditional cash transfers may be more effective, compared to unconditional transfers. Indeed,incentives conditional on marital status have been tried on a large scale in Haryana, India (the Apni Beti Apni Dhan program, Sinha and Yoong (2009)) and a recent working paper by Buchmann, Field, Glennerster, Nazneen, Pimkina, and Sen (2017) shows that conditional incentive programs on remaining unmarried till the age of 18 marriage are highly effective in increasing age at marriage in Bangladesh. An interesting avenue for future research lies in understanding the differential effect on child marriage of conditionality in cash transfer programs across contexts.

Designing successful policies to reduce child marriage – a goal that has received increasing attention because of its potentially large impact on human capital accumulation and economic development (Wodon, Male, Nayihouba, et al., 2017) – requires understanding the economic role of culture and institutions. More generally, our findings point to the importance of culture and institutions in influencing the external validity of natural experiments and to the value of replicating empirical and experimental analyses in different contexts, to fully understand the economic mechanisms behind empirical results.

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Table 1: Weather shocks, crop yields, and income in Sub-Saharan Africa

	Crop Yields						Income and Consumption	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Maize	Sorghum	Millet	Rice	Wheat	Average	GDP per capita	HH consumption
Drought	-0.11***	-0.13***	-0.08**	-0.11***	-0.06*	-0.12***	-0.05*	-0.07**
	(0.03)	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
N	1,850	1,693	1,593	1,605	1,253	1,818	1,455	1,335
Adjusted R^2	0.57	0.64	0.64	0.62	0.63	0.74	0.92	0.95

Note: * p<0.1, ** p<0.05, *** p<0.01
The dependent variable is the log of annual crop yield (tons per hectare, cols.1-6) or log of GDP and consumption (US $, cols. 7-8) for each included country from 1961 to 2010. Crop yield data are from FAOStat; income data are from the World Development Indicators from the World Bank, for 1960-2013. Regressions include all SSA countries in the FAOStat and WDI databases. In the columns labeled "Average", the dependent variable is the log of the sum of total production of main crops reported (maize, sorghum, millet, rice, and wheat) divided by the total area harvested for those crops. GDP per capita is measured in constant 2010 US$, while household final consumption expenditures are measured at the aggregate level in current US$. A drought is defined as an annual rainfall realization below the 15th percentile of the national rainfall distribution. Standard errors (in parentheses) are clustered at the country level. All regression specifications include year and country fixed effects.

Table 2: Weather Shocks, Crop Yields and Income in India

	Crop Yields						Income and Consumption (t+1)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Rice	Wheat	Jowar	Maize	Bajra	Average	NSDP p.c.	HH consumption
Drought	-0.18***	-0.05***	-0.18***	-0.04**	-0.19***	-0.16***	-0.04***	-0.02*
	(0.02)	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)
Mean of level	143.7	96.4	43.2	20.4	24.5	291.6	743.7	1218.5
N	8,208	7,670	7,118	7,563	6,054	8,672	434	149,436
Adjusted R^2	0.66	0.69	0.59	0.35	0.56	0.75	0.96	0.23

Note: * p<0.1, ** p<0.05, *** p<0.01
The dependent variable is the log of annual crop yield (tons per hectare) for each Indian district from 1957 to 1987, or net state domestic product per capita (1971 INR, 1961-1989), or household consumption (2011 INR, 1994-1998). Crop yield data are from the World Bank India Agriculture and Climate Dataset, NSDP data are from the Economic and Political Weekly Research Foundation India Time Series, and household consumption data are from the Indian National Sample Survey. In the columns labeled “Average”, the dependent variable is the log of the sum of total production of main crops reported (rice, wheat, jowar, maize, and bajra) divided by the total area harvested for those crops. A drought is defined as an annual rainfall realization below the 15th percentile of the local rainfall distribution (district level for cols. 1-6, state level for cols. 7-8). Standard errors (in parentheses) are clustered at the district level. All regression specifications include year and district fixed effects.

Table 3: Effect of Droughts on the Timing of Marriage

	SSA			India	
	(1)	(2)	(3)	(4)	(5)
Drought	0.0037***	0.0037***	0.0032***	-0.0041***	-0.0044***
	(0.0012)	(0.0012)	(0.0011)	(0.0016)	(0.0017)
Birth Year FE	Yes	Yes	Yes	Yes	Yes
Age FE	Yes	Yes	Yes	Yes	Yes
Country FE	No	Yes	Yes	No	No
Country FE × Cohort FE	No	No	Yes	No	No
State FE × Cohort FE	No	No	No	No	Yes
N	2,461,176	2,461,176	2,461,176	433,187	433,187
Adjusted R^2	0.062	0.062	0.062	0.091	0.091

Note: * p<0.1, ** p<0.05, *** p<0.01
Table shows OLS regressions for the Sub-Saharan Africa (SSA) and India full regression samples: women aged 25 or older at the time of interview. Observations are at the level of person × age (from 12 to 24 or age of first marriage). The dependent variable is a binary variable for marriage, coded to one if the woman married at the age corresponding to the observation. Standard errors (in parentheses) are clustered at the grid cell level (SSA) or district level (India). A drought is defined as an annual rainfall realization below the 15th percentile of the local rainfall distribution. All regression specifications include grid cell (SSA) or district (India) fixed effects. Regressions for SSA are weighted using country population-adjusted survey sampling weights.

Table 4: Effect of Droughts on Child Marriage

	SSA			India	
	(1)	(2)	(3)	(4)	(5)
Drought	0.0026**	0.0026**	0.0020*	-0.0046***	-0.0047***
	(0.0012)	(0.0012)	(0.0012)	(0.0016)	(0.0017)
Birth Year FE	Yes	Yes	Yes	Yes	Yes
Age FE	Yes	Yes	Yes	Yes	Yes
Country FE	No	Yes	Yes	No	No
Country FE × Cohort FE	No	No	Yes	No	No
State FE × Cohort FE	No	No	No	No	Yes
N	1,799,037	1,799,037	1,799,037	329,586	329,586
Adjusted R^2	0.071	0.072	0.072	0.082	0.082

Note: * p<0.1, ** p<0.05, *** p<0.01
Table shows OLS regressions for the Sub-Saharan Africa (SSA) and India full regression samples: women aged 25 or older at the time of interview. Observations are at the level of person × age (from 12 to 17 or age of first marriage, whichever is earlier). The dependent variable is a binary variable for marriage, coded to one if the woman married at the age corresponding to the observation. Standard errors (in parentheses) are clustered at the grid cell level (SSA) or district level (India). A drought is defined as an annual rainfall realization below the 15th percentile of the local rainfall distribution. All regression specifications include grid cell (SSA) or district (India) fixed effects. Regressions for SSA are weighted using country population-adjusted survey sampling weights.

Table 5: Effect of Drought on Child Marriage, by Marriage Payment Custom in Sub-Saharan-Africa

	BP $\geq$ 50%		BP $<$ 50%		Dowry (Eritrea)
	(1)	(2)	(3)	(4)	(5)
Drought	0.0026**	0.0026**	-0.00035	-0.00035	-0.012*
	(0.0013)	(0.0013)	(0.0019)	(0.0019)	(0.0064)
Birth Year FE	Yes	Yes	Yes	Yes	Yes
Age FE	Yes	Yes	Yes	Yes	Yes
Country FE	No	Yes	No	Yes	No
N	1,507,707	1,507,707	291,330	291,330	23,209
Adjusted R^2	0.073	0.074	0.058	0.058	0.032

Note: * p<0.1, ** p<0.05, *** p<0.01
Table shows OLS regressions for Sub-Saharan-Africa (SSA): women aged 25 or older at the time of interview. The dependent variable is a binary variable for marriage, coded to one if the woman married at the age corresponding to the observation. Columns 1-2 present the results for SSA countries with low prevalence of bride price (BP) custom ($<$ 50%), while the other columns present results for those with high BP custom ($>$ 50%), according to the Atlas of Pre-colonial Societies. Column 5 presents results for Eritrea, the only country in our SSA sample with a widespread dowry tradition. Observations are at the level of person $\times$ age (from 12 to 17 or age of first marriage, whichever is earlier). Standard errors (in parentheses) are clustered at the grid cell level. All regression specifications include grid cell fixed effects. A drought is defined as an annual rainfall realization below the 15th percentile of the local rainfall distribution. Results are weighted using country population-adjusted survey sampling weights. See Table A1 for traditional marriage customs by country.

Table 6: Effect of Weather Shocks on Child Marriage in India, with religious, regional, and cohort heterogeneity

	(1)	(2)	(3)	(4)	(5)
Drought	-0.0052***	-0.0061**	-0.0057***	-0.0049***	-0.0060**
	(0.0019)	(0.0028)	(0.0018)	(0.0018)	(0.0030)
Drought × non-Hindu	0.0025				
	(0.0037)				
	{0.39}				
Drought × Low Dowry		0.0027			
		(0.0034)			
		{0.089}			
Drought × non-Hindu × Low Dowry			0.0073*		
			(0.0042)		
			{0.67}		
Drought × South India				0.0013	0.016***
				(0.0038)	(0.0060)
				{0.28}	{0.055}
Drought × born 1960-69					0.0031
					(0.0045)
					{0.32}
Drought × born 1970-79					0.0010
					(0.0058)
					{0.28}
Drought × South × born 1960-69					-0.025***
					(0.0075)
					{0.0078}
Drought × South × born 1970-79					-0.019**
					(0.0095)
					{0.16}
Interacted birth year FE	Yes	Yes	Yes	Yes	Yes
Interacted age FE	Yes	Yes	Yes	Yes	Yes
N	329,294	329,586	329,294	329,586	329,586
Adjusted R^2	0.083	0.082	0.082	0.082	0.082

Note: * p<0.1, ** p<0.05, *** p<0.01
Table shows OLS regressions for the India full regression samples: women aged 25 or older at the time of interview. Observations are at the level of person × age (from 12 to 17 or age of first marriage, whichever is earlier). The dependent variable is a binary variable for marriage, coded to one if the woman married at the age corresponding to the observation. P-values of the linear combination of effects for the relevant sub-population are displayed in braces. States with low dowry (<50%) according to the ATLAS are Andaman/Nicobar Islands, Assam, Bihar, Dadra/Nagar Haveli, Delhi, Goa/Daman/Diu, Gujarat, Himachal Pradesh, Jammu/Kashmir, Kerala, Laccadive Islands, Madhya Pradesh, Mysore, Nagaland, Punjab, Tripura, Uttar Pradesh, and West Bengal. A drought is defined as an annual rainfall realization below the 15th percentile of the local rainfall distribution. All regression specifications include district fixed effects.

Table 7: Effect of Weather Shocks on Child Fertility in Sub-Saharan-Africa and India

	SSA			India	
	(1)	(2)	(3)	(4)	(5)
Drought	0.0022**	0.0022**	0.0018**	-0.00022	0.000012
	(0.00088)	(0.00088)	(0.00088)	(0.0011)	(0.0011)
Birth Year FE	Yes	Yes	Yes	Yes	Yes
Age FE	Yes	Yes	Yes	Yes	Yes
Country FE	No	Yes	Yes	No	No
Country FE × Cohort FE	No	No	Yes	No	No
State FE × Cohort FE	No	No	No	No	Yes
N	1,931,808	1,931,808	1,931,808	374,059	374,059
Adjusted R^2	0.047	0.047	0.048	0.057	0.057

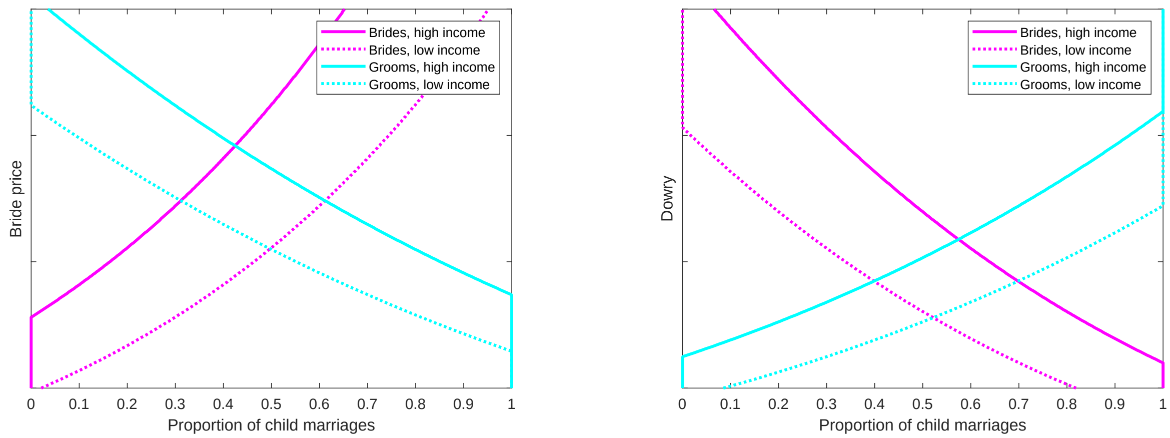
Note: * p<0.1, ** p<0.05, *** p<0.01
Table shows OLS regressions for Sub-Saharan Africa (SSA) and India: women aged 25 or older at the time of interview. Observations are at the level of person × age (from 12 to 17 or age of first birth, whichever is earlier). The dependent variable is a binary variable for fertility, coded to one if the woman had her first child at the age corresponding to the observation. Robust standard errors (in parentheses) are clustered at the grid cell level (in SSA) and district level (India) . All regression specifications include grid cell fixed effects (in SSA) and district level fixed effects (in India). A drought is defined as an annual rainfall realization below the 15th percentile of the local rainfall distribution. Results for SSA are weighted by country population-adjusted survey sampling weights.

Table 8: Weather Shocks and Marriage Payments for Child Marriage in India and Indonesia

	India REDS			Indonesia IFLS		
	(1)	(2)	(3)	(4)	(5)	(6)
Drought	-0.17*	-0.16*	-0.13	-0.45**	-0.45**	-0.50**
	(0.093)	(0.092)	(0.093)	(0.21)	(0.21)	(0.21)
				[0.108]	[0.104]	[0.092]
Marriage Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Bride's age FE	No	Yes	Yes	No	Yes	Yes
Bride's education	No	No	Yes	No	No	Yes
N	2,169	2,169	2,168	1,131	1,131	1,131
Adjusted R^2	0.39	0.40	0.43	0.16	0.15	0.18

Note: * p<0.1, ** p<0.05, *** p<0.01
Table shows OLS regressions based on deck 8 and 215 of the REDS data (col.1-3) and from the IFLS in Indonesia (cols. 4-6). Observations are at the level of a marriage. Robust standard errors (in parentheses) are clustered at the district level in India and province in Indonesia. P-values in square brackets are wild bootstrapped clustered at the province level. A drought is defined as an annual rainfall realization below the 15th percentile of the local rainfall distribution. All regression specifications include district (India) or province (Indonesia) fixed effects.

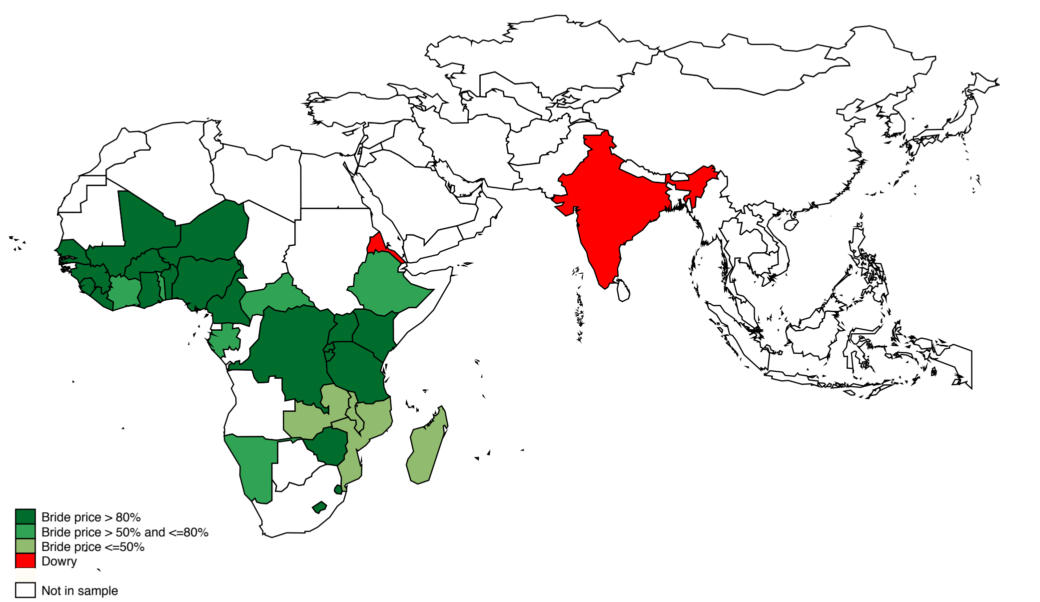
Figure 1: Equilibrium outcomes



(a) Sub-Saharan Africa (b) India

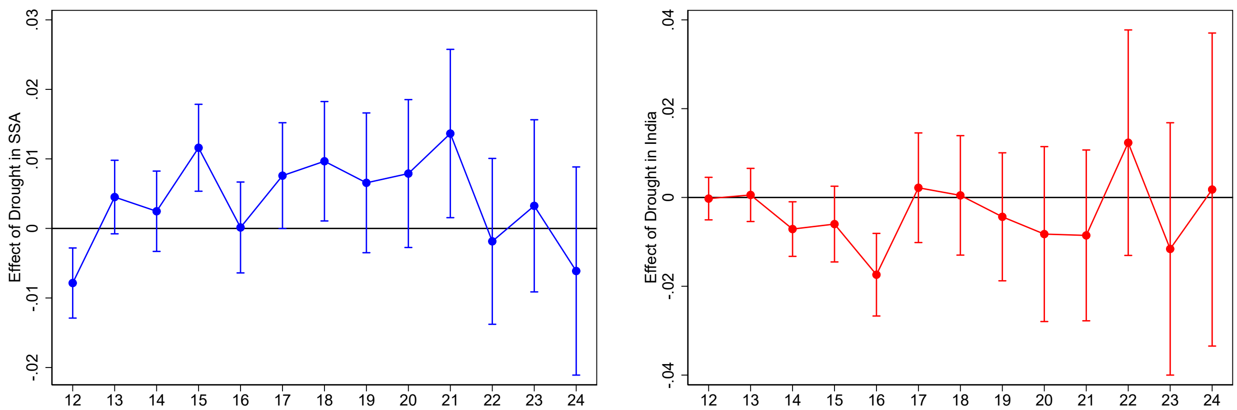
Note: Figures show the marriage market response to a negative income shock under bride price (Sub-Saharan Africa) or dowry (India), using a constant relative risk aversion (CRRA) utility function. The groom's side is displayed in blue and the bride's side in pink. Solid lines represent supply and demand curves with high aggregate income, whereas dotted lines represent supply and demand with low aggregate income.

Figure 2: Map of marriage payment traditions by country in the main sample



Note: Data on bride price prevalence from the *Atlas of Pre-Colonial Societies*.

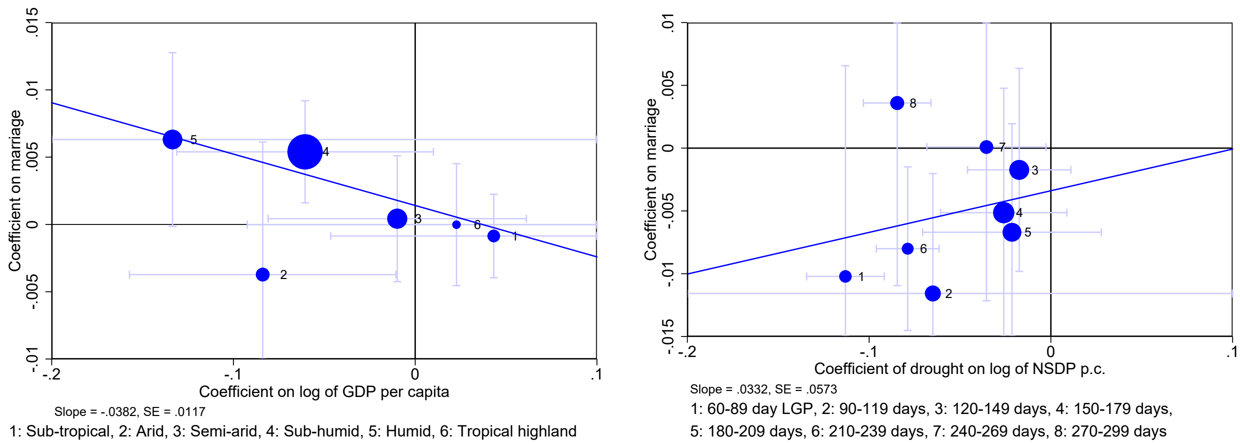
Figure 3: Effect of Droughts on Marriage by Age



(a) SSA (b) India

Note: Figure shows the effect of droughts by age estimated using the full Sub-Saharan Africa (SSA) and India regression samples. The connected points show the estimated coefficients and the capped spikes show 95% confidence intervals calculated using standard errors clustered at the grid cell (SSA) or district (India) level.

Figure 4: Coefficient of drought on log of per capita income and marriage, by agro-ecological zone



(a) SSA (b) India

Note: These graphs plot the coefficients and confidence intervals of drought on log of per capita income (country-wide GDP for SSA and net state domestic product for India) and on marriage by agro-ecological zone (AEZ); each point corresponds to an AEZ. Coefficients on marriage are computed at the person $\times$ age level, with fixed effects for AEZ $\times$ birth year, AEZ $\times$ age, and grid cell (SSA) or district (India), and standard errors clustered by grid cell or district. Coefficients on log of per capita income are computed at the country $\times$ year (SSA) or state $\times$ year (India) level, with fixed effects for year and country or state, and standard errors clustered by country or state. Indian per capita income is regressed on the first lag of drought. Marker size corresponds to the number of observations in each AEZ from marriage regressions.

Age of Marriage, Weather Shocks, and the Direction of Marriage Payments

Online Appendix

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A Theoretical Appendix

A.1 Proof of proposition 1

A household i wants its daughter to get married by the end of the second period if and only if:

$$\begin{aligned} & \frac{(y_2+\varepsilon_{2i}+\tau_2)^{1-\gamma}}{1-\gamma}+\xi^f > \frac{(y_2+\varepsilon_{2i}+w_2^f)^{1-\gamma}}{1-\gamma} \\ \iff \quad & \tau_2 > [(y_2+\varepsilon_{2i}+w_2^f)^{1-\gamma}-(1-\gamma)\xi^f]^{\frac{1}{1-\gamma}}-y_2-\varepsilon_{2i}=\underline{\tau_2} \end{aligned}$$

For household j with a son, we follow similar algebra:

$$\begin{aligned} & \frac{(y_2+\varepsilon_{2j}+w_2^m+w_2^f-\tau_2)^{1-\gamma}}{1-\gamma}+\xi^m > \frac{(y_2+\varepsilon_{2j}+w_2^m)^{1-\gamma}}{1-\gamma} \\ \iff \quad & \tau_2 < y_2+\varepsilon_{2j}+w_2^m+w_2^f-[(y_2+\varepsilon_{2j}+w_2^m)^{1-\gamma}-(1-\gamma)\xi^m]^{\frac{1}{1-\gamma}}=\overline{\tau_2} \end{aligned}$$

For $\xi^s \geq 0$, we have that $\overline{\tau_2} \geq \underline{\tau_2}$, with a strict inequality when either of the two ξ^s is strictly positive. Hence, there exists a $\tau_2^* \in [\underline{\tau_2}, \overline{\tau_2}]$ that would ensure that everyone marries.

When $\xi^f < \frac{(y_2+\varepsilon_{2i}+w_2^f)^{1-\gamma}}{1-\gamma} - \frac{(y_2+\varepsilon_{2i})^{1-\gamma}}{1-\gamma}$, then $\underline{\tau_2} > 0$ and the payment ought to be a bride price. When $\xi^m < \frac{(y_2+\varepsilon_{2j}+w_2^m)^{1-\gamma}}{1-\gamma} - \frac{(y_2+\varepsilon_{2j}+w_2^m+w_2^f)^{1-\gamma}}{1-\gamma}$, then $\overline{\tau_2} < 0$ and the payment ought to be a dowry.

Also, $\frac{\partial \underline{\tau_2}}{\partial \xi^f} < 0$ and $\frac{\partial \overline{\tau_2}}{\partial \xi^m} > 0$, ensuring that large enough preference realizations can make marriage payments based on historical $\tilde{w}^f$ sustainable even as w_2^f changes.

A.2 Proof of proposition 2

First, define $\Omega^f = \delta\left\{E\left[V_2^f(M_0)\right] - E\left[V_2^f(M_1)\right]\right\}$ as the option value of marriage for a woman's family and $\Omega^m = \delta\left\{E\left[V_2^m(M_0)\right] - E\left[V_2^m(M_1)\right]\right\}$ as the option value of marriage for a man's family. Note that $sgn(\tau_1) = sgn(\Omega^f) = -sgn(\Omega^m)$.

A woman's family would want her to marry in the first period if and only if

$$W(y_1, \epsilon_{1i}, \tau_1) \equiv u(y_1+\epsilon_{1i}+w_1^f+(\tau_1-w_1^f)) - u(y_1+\epsilon_{1i}+w_1^f) - \Omega^f > 0. \qquad (2)$$

Concavity and monotonicity of the utility function ensure that the right hand side of equation 2 is strictly decreasing in ϵ_{1i}, while Ω^f does not depend on it. Hence, the threshold ϵ^{*f} is defined implicitly as $W(y_1, \epsilon^*_f, \tau_1) \equiv 0$.

Similarly, a man's family would want him to marry in the first period if and only if

$$H(y_1, \epsilon_{1j}, \tau_1) \equiv u(y_1 + \epsilon_{1j} + w^m_1 - (\tau_1 - w^f_1)) - u(y_1 + \epsilon_{1j} + w^m_1) - \Omega^m > 0. \tag{3}$$

Again, concavity and monotonicity of the utility function ensure that the right hand side of equation 3 is strictly increasing in ϵ_{1j}, while Ω^m does not depend on it. Hence, the threshold ϵ^{*m} is defined from $H(y_1, \epsilon^*_m, \tau_1) \equiv 0$. Also, as long as w^m_2 is sufficiently large, concavity also ensures that $|\Omega^m| < |\Omega^f|$ (marriage payments have a greater impact on the budget constraint of a woman's family than on that of a man's family) and that $\epsilon^*_m > \epsilon^*_f$.

A.3 Proof of proposition 3

Under bride price, given the above-defined thresholds, the supply and the demand for brides are equal to

$$S(\tau_1, y_1) = F(\epsilon^{*f}(\tau_1, y_1)) \qquad\qquad D(\tau_1, y_1) = 1 - F(\epsilon^{*m}(\tau_1, y_1)).$$

Under dowry, the supply and the demand for brides are equal to

$$S(\tau_1, y_1) = 1 - F(\epsilon^{*f}(\tau_1, y_1)) \qquad\qquad D(\tau_1, y_1) = F(\epsilon^{*m}(\tau_1, y_1)).$$

By the implicit function theorem (IFT), the chain rule and the fact that $F'(\cdot) = f(\cdot) > 0$ (continuity), we have that

$$\frac{\partial S(\tau_1, y_1)}{\partial y_1} = S_y(\tau_1, y_1) = f(\epsilon^*_f(\tau_1, y_1)) \frac{\partial \epsilon^*_f(\tau_1, y_1)}{\partial y_1} = -f(\epsilon^*_f(\tau_1, y_1)) \frac{\partial W/\partial y_1}{\partial W/\partial \epsilon^*_f}$$
$$\frac{\partial D(\tau_1, y_1)}{\partial y_1} = D_y(\tau_1, y_1) = -f(\epsilon^*_m(\tau_1, y_1)) \frac{\partial \epsilon^*_m(\tau_1, y_1)}{\partial y_1} = f(\epsilon^*_m(\tau_1, y_1)) \frac{\partial H/\partial y_1}{\partial H/\partial \epsilon^*_m}.$$

Given the expressions for $W()$ in 2 and for $H()$ in 3, we have that, in the bride price case (with $\tau_1 \geq w^f_1$)

$$\frac{\partial S(\tau_1, y_1)}{\partial y_1} = S_y(\tau_1, y_1) = -f(\epsilon^*_f(\tau_1, y_1)) < 0, \qquad \frac{\partial D(\tau_1, y_1)}{\partial y_1} = D_y(\tau_1, y_1) = f(\epsilon^*_m(\tau_1, y_1)) > 0.$$

and in the dowry case (with $\tau_1 \leq w^f_1$)

$$\frac{\partial S(\tau_1, y_1)}{\partial y_1} = S_y(\tau_1, y_1) = f(\epsilon^*_f(\tau_1, y_1)) > 0, \qquad \frac{\partial D(\tau_1, y_1)}{\partial y_1} = D_y(\tau_1, y_1) = -f(\epsilon^*_m(\tau_1, y_1)) < 0.$$

In sum, $sgn(\tau_1) = -sgn(S_y(\tau_1, y_1)) = sgn(D_y(\tau_1, y_1))$.

A.4 Proof of proposition 4

The equilibrium quantity of child marriage is given by $Q_1^*(y_1) \equiv D(y_1, \tau_1^*) = S(y_1, \tau_1^*)$. Hence, $\frac{dQ^*(y_1)}{dy_1} = S_y(y_1, \tau_1^*) + S_\tau(y_1, \tau_1^*) \frac{\partial \tau_1^*}{\partial y_1}$. In both economies, equilibrium prices are defined implicitly as the solution to $S(y_1, \tau_1^*) - D(y_1, \tau_1^*) = 0$. This implies that, by the IFT, $\frac{d\tau_1^*}{dy_1} = -\frac{S_y - D_y}{S_\tau - D_\tau}$ and that

$$\frac{dQ^*(y_1)}{dy_1} = S_y - S_\tau \frac{S_y - D_y}{S_\tau - D_\tau}.$$

After some manipulations and applying the above derivations on the signs of the partial derivatives of supply and demand, we obtain that,

$$sgn\left(\frac{dQ^*(y_1)}{dy_1}\right) = sgn\left(\frac{S_y}{S_\tau} - \frac{D_y}{D_\tau}\right).$$

This derivation implies the classic result that equilibrium quantities (of child marriage) vary according to aggregate income depending on the relative elasticities of demand and supply with respect to both prices and income.

With similar argument used above, we have that

$$\begin{aligned}
\frac{\partial S(\tau_1, y_1)}{\partial \tau_1} &= S_\tau(\tau_1, y_1) = f(\epsilon_f^*(\tau_1, y_1)) \frac{\partial \epsilon_f^*(\tau_1, y_1)}{\partial \tau_1} = -f(\epsilon_f^*(\tau_1, y_1)) \frac{\partial W/\partial \tau_1}{\partial W/\partial \epsilon_f^*} \\
\frac{\partial D(\tau_1, y_1)}{\partial \tau_1} &= D_\tau(\tau_1, y_1) = -f(\epsilon_m^*(\tau_1, y_1)) \frac{\partial \epsilon_m^*(\tau_1, y_1)}{\partial \tau_1} = f(\epsilon_m^*(\tau_1, y_1)) \frac{\partial H/\partial \tau_1}{\partial H/\partial \epsilon_m^*}.
\end{aligned}$$

and ultimately

$$sgn\left(\frac{dQ^*(y_1)}{dy_1}\right) = sgn\left(\frac{\partial W/\partial y_1}{\partial W/\partial \tau_1} - \frac{\partial H/\partial y_1}{\partial H/\partial \tau_1}\right).$$

Given these derivations of these partial derivatives and the marginal utility of a CRRA, we have that:

$$\begin{aligned}
&\frac{S_y}{S_\tau} - \frac{D_y}{D_\tau} \\
=&\frac{u'(y_1 + \epsilon_f^* + w_1^f + (\tau_1 - w_1^f)) - u'(y_1 + \epsilon_f^* + w_1^f)}{u'(y_1 + \epsilon_f^* + w_1^f + (\tau_1 - w_1^f)} - \frac{u'(y_1 + \epsilon_m^* + w_1^m - (\tau_1 - w_1^f)) - u'(y_1 + \epsilon_m^* + w_1^m)}{u'(y_1 + \epsilon_m^* + w_1^m - (\tau_1 - w_1^f))} \\
=&2 - \left(1 + \frac{\tau_1 - w_1^f}{y_1 + \epsilon_f^* + w_1^f}\right)^\gamma - \left(1 - \frac{\tau_1 - w_1^f}{y_1 + \epsilon_m^* + w_1^m}\right)^\gamma.
\end{aligned}$$

By the Bernoulli inequality $((1+x)^r \geq 1 + rx \ \forall r \geq 1, x \geq -1)$, with $\gamma \geq 1$ the above expression is bounded from above by the term

$$\gamma(\tau_1 - w_1^f)\left(\frac{1}{y_1 + \epsilon_m^* + w_1^m} - \frac{1}{y_1 + \epsilon_f^* + w_1^f}\right)$$

By the related inequality stating that $(1+x)^r \leq 1 + \frac{rx}{1-rx}\ \forall r \geq 0, x \in \left(-1, \frac{1}{r}\right)$, when suitable conditions on the parameters are met,[35] the expression is bounded from below by the term

$$\gamma(\tau_1 - w_1^f)\left(\frac{1}{y_1 + \epsilon_m^* + w_1^m - \gamma(w_1^f - \tau_1)} - \frac{1}{y_1 + \epsilon_f^* + w_1^f - \gamma(\tau_1 - w_1^f)}\right).$$

In bride price societies, where $\tau_1 > w_1^f$, the upper bound of the expression is negative whenever $w_1^m + \epsilon_m^* > w_1^f + \epsilon_f^*$. In dowry societies, where $\tau_1 < w_1^f$, the lower bound of the expression is positive whenever $w_1^m + \epsilon_m^* > w_1^f + \epsilon_f^* + 2\gamma(w_1^f - \tau_1)$. Hence, in both cases, the expression has the expected sign when w_2^m (in the second period) is sufficiently large, which would increase ϵ_m^*.

In the special case in which utility is logarithmic ($\gamma = 1$), the above condition becomes

$$sgn\left(\frac{dQ^*(y_1)}{dy_1}\right) = sgn\left(-\frac{w_1^f - \tau_1}{y_1 + \epsilon_m^* + w_1^m} + \frac{w_1^f - \tau_1}{y_1 + \epsilon_f^* + w_1^f}\right)$$

and has the expected sign whenever $w_1^m + \epsilon_m^* > w_1^f + \epsilon_f^*$.

A.5 Proof of proposition 5

As described above, equilibrium prices are defined implicitly as the solution to

$$S(\tau_1^*, y_1) - D(\tau_1^*, y_1) = 0.$$

By the IFT, the derivative of the equilibrium price with respect to y_1 is

$$\frac{d\tau_1^*}{dy_1} = -\frac{S_y(\tau_1, y_1) - D_y(\tau_1, y_1)}{S_\tau(\tau_1, y_1) - D_\tau(\tau_1, y_1)}.$$

Based on proposition 3, this derivative is positive in the case of bride price and negative in the case of dowry, which implies that marriage payments are lower when income is lower regardless of whether bride price or dowry prevails.

[35] Specifically, that both $\frac{w_1^f - \tau_1}{y_1 + \epsilon_m^* + w_1^m}$ and $\frac{\tau_1 - w_1^f}{y_1 + \epsilon_f^* + w_1^f}$ are elements of the interval $\left(-1, \frac{1}{\gamma}\right)$.

A.6 Robustness: effects of droughts on w^f and w^m

We now consider an extension of the model that allows the children's contributions to the budget constraint to depend on contemporaneous droughts, i.e. it allows for $\frac{dw_t^s(y_t)}{dy_t} \neq 0$ for $s \in \{m, f\}$. Based on evidence from the literature, we expect that droughts would compress wages, i.e. that $\frac{dw_t^s(y_t)}{dy_t} \geq 0$ when $w_t^s > 0$. For the case in which women consume more than they contribute to the budget constraint ($w_t^f < 0$), which at leats historically mights have happened in India, we expect that their consumption would be lower with droughts, leading to $\frac{dw_t^f(y_t)}{dy_t} \leq 0$.

We first examine Proposition 3. Taking the appropriate partial derivatives, we have that

$$S_y(\tau_1, y_1) = -sgn(\tau_1 - w_1^f) f(\epsilon_f^*) \left(1 - \frac{dw_1^f}{dy_1} \frac{u'(y_1 + \epsilon_f^* + w_1^f)}{u'(y_1 + \epsilon_f^* + w_1^f + (\tau_1 - w_1^f)) - u'(y_1 + \epsilon_f^* + w_1^f)}\right)$$

$$D_y(\tau_1, y_1) = sgn(\tau_1 - w_1^f) f(\epsilon_m^*) \left(1 + \frac{dw_1^m}{dy_1} + \frac{dw_1^f}{dy_1} \frac{u'(y_1 + \epsilon_m^* + w_1^m - (\tau_1 - w_1^f))}{u'(y_1 + \epsilon_m^* + w_1^m - (\tau_1 - w_1^f)) - u'(y_1 + \epsilon_m^* + w_1^m)}\right).$$

This means that Proposition 3 is unaffected by $\frac{dw_1^m(y_t)}{dy_t}$ when this is positive instead of zero. In the bride price case, allowing for $\frac{dw_1^f(y_1)}{dy_1} > 0$ makes households even *more* responsive to droughts: during droughts, young daughters and young daughters-in-law become less productive, making the partial-equilibrium response of demand and supply ($S_y(\tau_1, y_1)$ and $D_y(\tau_1, y_1)$) even larger in absolute value. In the dowry case, on the contrary, it is allowing for $\frac{dw_1^f(y_1)}{dy_1} < 0$ that makes households more responsive to droughts. This implies that for Proposition 3 to hold in a dowry societies, any negative effect of droughts on the wages of young women need not be so large that, for instance, daughters move from being productive to being very costly. This is because, in such a case, parents may prefer to have their daughter marry sooner if her productivity drops substantially, and the grooms family may find the temporarily unproductive bride less attractive. Note that when Proposition 3 holds, so does Proposition 5.

We hence are left to study Proposition 4. Irrespective of the effects of droughts on wages, we continue having that $sgn\left(\frac{dQ^*(y_1)}{dy_1}\right) = sgn\left(\frac{S_y}{S_\tau} - \frac{D_y}{D_\tau}\right)$. The term that determines the sign, in this case, is equal to

$$\frac{S_y}{S_\tau} - \frac{D_y}{D_\tau} = 2 - \left(1 + \frac{\tau_1 - w_1^f}{y_1 + \epsilon_f^* + w_1^f}\right)^\gamma - \left(1 - \frac{\tau_1 - w_1^f}{y_1 + \epsilon_m^* + w_1^m}\right)^\gamma$$
$$+ \frac{dw_1^f}{dy_1}\left[1 - \left(1 + \frac{\tau_1 - w_1^f}{y_1 + \epsilon_f^* + w_1^f}\right)^\gamma\right] + \frac{dw_1^m}{dy_1}\left[1 - \left(1 - \frac{\tau_1 - w_1^f}{y_1 + \epsilon_m^* + w_1^m}\right)^\gamma\right].$$

Given this expression, in order for the proof of Proposition 4 to hold, two conditions are sufficient. The first one is that w_2^m is sufficiently large relative to w_2^f so that $\epsilon_m^* > \epsilon_f^*$, irrespective of droughts. This condition appears to be reasonable, and indeed likely since men have access to more opportunities to smooth wage shocks, such as seasonal migration or off-farm employment, compared to women. Relatedly, the second sufficient condition requires that wages of young women would need to be at least as sensitive to droughts as those of men ($\frac{dw_1^m}{dy_1} \leq \frac{dw_1^f}{dy_1}$).

In sum, in the bride price case, hence, allowing droughts to affect w^f and w^m does not modify the predictions of the model under tenable assumptions. For the dowry case, there are two possible scenarios. If young women are on net productive ($w_1^f > 0$ and $\frac{dw_1^f}{dy_1} \geq 0$) our most important prediction, Proposition 4, is also going to continue holding under the same assumptions. Proposition 3, and consequently Proposition 5, may however not hold if the drop in a young woman's productivity with droughts is so large that parents find it too burdensome to wait to allow her to marry. If women are on net unproductive ($w_1^f < 0$ and $\frac{dw_1^f}{dy_1} \leq 0$), then for Proposition 4 to hold, the decline in young men's wages with droughts needs to be not too large relative to women's decline in consumption. Such condition can be met more easily if we think that, if households can reduce a young woman's consumption in drought, they may be able to do the same with a young man's consumption, mitigating the negative effect of droughts on his net contribution to the household budget.

A.7 Extension: household composition

Consider a woman with n_{bro} brothers and n_{sis} younger sisters. Older sisters have already married and hence do not appear in the problem. For simplicity, assume that none of the siblings is at marriageable age. Her parents will want her to marry if and only if

$$\begin{aligned} &u(y_1 + \epsilon_{1i} + n_{bro}w_1^m + n_{sis}w_1^f + \tau_1) - u(y_1 + \epsilon_{1i} + n_{bro}w_1^m + (n_{sis}+1)w_1^f) \\ &> \delta \left\{ E\left[V_2^f(M_0; n_{bro}, n_{sis})\right] - E\left[V_2^f(M_1; n_{bro}, n_{sis})\right] \right\}. \end{aligned}$$

With bride price, when utility is CRRA, an increase in the number of children reduces the probability that the above expression is satisfied as y_1 decreases when $\tau_1 > w_1^f$.

It is worth emphasizing that if all households have the same number of sons and daughters at marriageable age, then there would be no asymmetry between the demand and the supply of brides in terms of price and income elasticities. Hence, allowing for multiple children requires assuming that, since each respondent has in expectation the same number of brothers and sisters, her family of origin is likely to have more daughters than sons.[36]

[36]This is a testable assumption. In the DHS data on household composition from Africa that we exploit in subsection 7.2, our respondents have on average 2.55 sisters and 2.59 brothers. Hence, conditional on having at least one daughter (the respondent), the gender composition of the children in the households in which respondents grew up is 61% (including the respondent) female and 39% male. Households with the modal and median number of children, which is quite large at 6, have a composition that is 58% female and 42% male.

A.8 Extension: variation in sex ratios in dowry societies

Consider now a dowry society in which there exists a measure one of men and a measure $r \leq 1$ of women, i.e. there may be fewer women than men, as occurs in parts of India. There are three consequences of this setting. The first one is that dowry $(-\tau_2^*)$ could be smaller due to competition in the marriage market. The second is that the option value Ω^m would be lower as r decreases, as men risk to remain single in the second period. In particular, the man's value of entering period 2 as single is lower in expectation:

$$E\left[V_2^m(M_0; r)\right] = r\left[u(y_2 + \epsilon_{2j} + w_1^m + w_1^f - \tau_2^*(r)) + \xi^m\right] + (1-r)u(y_2 + \epsilon_{2j} + w_1^m)$$

These two reasons would hence imply that, as r declines, Ω_r^m would decrease and Ω_r^f would increase. Hence, we should expect that the more male-biased the sex ratios are (smaller r), the larger ϵ_m^* would be and the smaller ϵ_f^* would be. Moreover, if the bias in the sex ratio is orthogonal to idiosyncratic income, then the supply of brides is equal to $S(\tau_1, y_1, r) = r\left[1 - F(\epsilon^{*f}(\tau_1, y_1, r))\right]$. These forces strengthen the probability that the below condition holds

$$2 - \left(1 + \frac{w_1^f - \tau_1}{y_1 + \epsilon_m^* + w_1^m}\right)^\gamma - \left(1 - \frac{w_1^f - \tau_1}{y_1 + \epsilon_f^* + w_1^f}\right)^\gamma > 0,$$

exacerbating the effect of droughts on child marriage for biased sex ratios (i.e. $\frac{\partial^2 Q_1(\tau_1, y_1, r)}{\partial y_1 \partial r}$). We prove a proposition of this intuition in the special case of linear supply and demand curves below.

Proposition 6. *Under dowry, when $\gamma = 1$ and $F(\,)$ is a uniform distribution between 0 and 1, the derivative $\frac{\partial Q_1^*(\tau_1, y_1, r)}{\partial r}$ and the cross-partial derivative $\frac{\partial^2 Q_1^*(\tau_1, y_1, r)}{\partial y_1 \partial r}$ are both negative.*

Proof. Define $H_r^f = exp(\Omega_r^f)$ and $H_r^m = exp(\Omega_r^m)$. With dowry, $H_r^f \leq 1$, $H_r^m \geq 1$ and, given our assumption about $w_1^m > w_1^f$, $H^m + H^f - 2 < 0$. The equilibrium child marriage quantity is equal to $Q^*(\tau_1, y_1, r) = \frac{(H_r^f - 1)(H_r^m - 1)[(r+1)y_1 + r]}{H_r^f - rH_r^m + r - 1}$. The derivative with respect to the sex ratio is $-\frac{(1+r)(H_r^f - 1)(H_r^m - 1)}{r(H_r^f - 1 - r(H_r^m - 1))} < 0$. The cross-partial derivative is equal to

$$\frac{(H_r^m - 1)\left[r(r+1)(H_r^m - 1)\frac{dH_r^f}{dr} - (H_r^f - 1)(H_r^f + H_r^m - 2)\right] - (r+1)(H_r^f - 1)^2\frac{dH_r^m}{dr}}{(H_r^f - 1 - r(H_r^m - 1))^2} < 0.$$

□

Note that unbalanced sex ratios are likely to modify household compositions in ways that may attenuate our effects, by giving respondents more brothers than sisters on average. We discuss this limitation in subsection 7.3.

B Constructing a concordance between the Atlas of Pre-Colonial Societies and the DHS

To match individuals to the ATLAS, we used the DHS's variable for ethnic group (v131). We first checked for a direct match between the name of the ethnic group listed and a group within the Atlas. In many cases, the DHS codes individuals into broad sets of several ethnic groups, which will not immediately yield a match. For example, some observations in Mali are coded as "Sarakole/Soninke/Marka." In cases like these, we looped through the names of the ethnic groups in the category until either a direct match with the Atlas was found or all names failed to match. We term the 138,136 individuals who were matched either immediately or by looping through these ethnic groups as a "verbatim match".

For those individuals who still were not matched after this process, we used a wide array of sources to look for alternative names or spellings of their ethnic group which would match to entries in the ATLAS. Focusing on the initially unmatched groups with the most observations, we managed to match an additional 101,223 individuals to the ATLAS.

C Analysis of long-run effects on fertility and of effects on school dropout

To study the long-term effects of droughts on fertility, we follow Burke, Gong, and Jones (2015) and we define our main explanatory variable as a dummy for whether the woman experienced a droughts over different age ranges. Hence, we run the following specification for woman i living in location g and born in year k:

$$y_{i,g,k} = X_{g,k,t}\beta + Z_{i,g}\delta + \omega_g + \gamma_k + \zeta_i + \epsilon_{i,g,k,t}. \tag{4}$$

In this specification, y represents two outcome variables: the age of marriage and the total number of children, while X is a vector containing the number of droughts that woman i has experienced over age ranges 12-14 and 15-17. In addition to location and year-of-birth fixed effect, we control for country fixed effects and, in Sub-Saharan Africa, for current age at the time of the survey.

We find that experiencing any drought between ages 15 and 17 increases the probability of child marriage by 0.88pp in SSA (table A10 column 1, $p < 0.01$) and reduces such a probability by 0.96pp in India (column 3, $p < 0.05$). At the same time, it raises the number of children that a woman in SSA has by age 25 by 0.055 (column 2, $p < 0.01$), while has a negative, but not statistically significant effect on the same variable in India (column 4). While the timing of marriage is likely an important channel of this shift in fertility behavior, other factors, such as changes in education and human capital, should also play a role, in particular in the earlier ages.

As documented in a large body of literature (for example, see Bjorkman Nyqvist (2013); Shah and Steinberg (2017)), rainfall shocks are likely to influence school dropout rates in developing countries. While data on the timing of school dropout is not present in the DHS, we combine information about the onset of primary school in each country in our sample with individual information about years of education to obtain an approximate age of school dropout. We then create a variable that takes value 1 in the year in which a woman drops out of school and zero beforehand, similar to our marriage specification, to examine the relationship between droughts and school dropout between ages 6 and 17. To address the measurement error in the year of droupout, we consider a dummy that takes value 1 if a drought occurs in year t, $t-1$ and $t+1$ as our primary independent variable.

Our findings are in line with the hypothesis that child marriage and schooling may be substitutes (Field and Ambrus, 2008). Between ages 6 and 11, droughts increase the hazard of school dropout in a virtually identical fashion in both SSA and India, by 0.27pp (Table A11, columns 2 and 4, $p < 0.10$ in both instances). However, between ages 12 and 17, when the hazard into child marriage increase with droughts in SSA and decreases in India, we find that droughts strongly increase school dropouts in SSA, by 0.72pp (column 2, $p < 0.05$) while they have a non-statistically significant negative effect on school dropouts of 0.53pp (column 4).

D Characteristics of the spouses and of the matches by weather realization

Who matches during a drought? To examine the characteristics of marriages that form during years of drought, we estimate the following equation, for household i living in location g (grid cell in Sub-Saharan Africa, district in India) born in cohort k and married in year τ:

$$y_{i,g,k,\tau} = X_{g,k,\tau}\beta + \delta_\tau + \omega_g + \gamma_k + \zeta_i + \epsilon_{i,g,k,\tau}. \tag{5}$$

In this specification, $X_{g,k,\tau}$ are time-varying measures of weather conditions (i.e. droughts) in location g during the year in which the woman marries τ. We control for location fixed effects ω_g, for current age (at the time of the survey) fixed effects ζ_i, for year of birth γ_k, and for year of marriage δ_τ. It is important to notice that we cannot assign any causal interpretation to these estimates, as they are the result of both selection forces (i.e. the characteristics of individuals who chose to marry during a drought may differ from those who didn't) and causal forces (i.e. the fact that a couple married during a drought may lead to different long-term outcomes).[37]

In Sub-Saharan Africa, we find that the women who marry during droughts are 1.2 percentage

[37] In India, when we are using a cross-sectional dataset from 1998, current age and birth year are collinear and hence it is sufficient to control for year-of-birth fixed effect (i.e. ζ_i is not identified).

points more likely to be uneducated (table A12, column 1, $p < 0.05$), and they tend to marry men of similar education and age as those who marry during regular times (columns 2-3). They are not more likely to be in polygynous marriages, but may be slightly more likely to be a first wife in a polygynous union, possibly because of the earlier marriage (columns 4 and 5). Finally, they are 0.05pp more likely to have no say in household 's decisions (column 6, $p < 0.05$).[38]

In the data from India, we find no significant differential patterns among the couples that form during droughts and those who don't (columns 7-10). An additional analysis shows that lack of power is the most plausible explanation: when we combine data from the 1998 DHS with data from the 2005 IHDS, we find opposite patterns compared to those documented for Sub-Saharan Africa. In particular, women who marry during droughts are 1.6pp less likely to be uneducated (Appendix table A13, column 1, $p < 0.10$) and are 1.2 less likely to have "no say" in household's decisions (column 4, $p < 0.10$).

Overall, these results are in line with our model in which households differ in the realization of the idiosyncratic shock. The most disadvantaged women marry during droughts when a bride price payments is expected. Instead, when a dowry payment is expected, it is the relatively more advantaged women who can afford to marry during droughts.

E Appendix Tables and Figures

[38]This variable compounds 4 questions about who makes decisions in the household in different realms. We classify the woman as having no say in decision n if she replies that it is the husband alone who makes that decision. The questions are: i) Who usually decides how the money you earn will be used: you, your husband/partner, or you and your husband/partner jointly? ii)Who usually makes decisions about health care for yourself: you, your husband/partner, you and your husband/partner jointly, or someone else? iii) Who usually makes decisions about making major household purchases? iv) Who usually makes decisions about visits to your family or relatives? Hence, the maximum value that the variable "no say" can take is 4 , and the minimum is 0.

Table A1: Traditional Marriage Customs in Sub-Saharan Africa

Country	% bride price	Country	% bride price
Benin	91%	Mali	93%
Burkina Faso	83%	Mozambique	43%
Burundi	99%	Namibia	58%
Cameroon	93%	Niger	100%
Central African Republic	65%	Nigeria	91%
Eritrea	45%	Rwanda	100%
Ethiopia	66%	Senegal	98%
Gabon	74%	Sierra Leone	99%
Ghana	94%	Swaziland	97%
Guinea	95%	Tanzania	81%
Ivory Coast	69%	Togo	62%
Kenya	100%	Uganda	97%
Lesotho	100%	Zaire	84%
Liberia	98%	Zambia	19%
Madagascar	13%	Zimbabwe	87%
Malawi	15%		

Note: Data from the *Atlas of Pre-Colonial Societies* (available at http://www.worlddevelopment.uzh.ch/en/atlas.html, last accessed on August 13, 2018).

Table A2: Summary Statistics of the Regression Samples for Sub-Saharan Africa and India

	SSA			India		
	Obs	Mean	Std. Dev.	Obs	Mean	Std. Dev.
Panel A: Unique individuals						
Age of first marriage	306,265	18.59	4.37	66,466	17.67	3.62
Percent married between ages 12 and 17	326,645	44.69	49.72	66,466	54.08	49.83
Percent married between ages 12 and 24	326,645	84.64	36.06	66,466	94.72	22.36
Age of first child	308,445	19.56	3.91	63,799	19.56	3.71
Percent with first child between ages 12 and 17	326,645	30.56	46.07	66,466	30.22	45.92
Percent with first child between ages 12 and 24	326,645	84.27	36.41	66,466	86.43	34.24
Number of children	326,645	4.40	2.70	66,466	3.54	2.04
Number of droughts between ages 12 and 17	326,645	1.05	0.99	66,466	0.92	0.84
Number of droughts between ages 12 and 24	326,645	2.26	1.41	66,466	1.93	1.12
Percent Hindu	.	.	.	66,409	77.43	41.80
Panel B: Survival data						
Age	2,461,176	16.13	3.28	433,187	15.55	2.95
Percent married between ages 12 and 17	1,799,037	8.76	28.27	329,586	10.91	31.17
Percent married between ages 12 and 24	2,461,176	11.34	31.71	433,187	14.53	35.24
Percent with first child between ages 12 and 17	1,931,808	5.56	22.92	374,059	5.37	22.54
Percent with first child between ages 12 and 24	2,754,577	9.75	29.67	560,616	10.25	30.33
Percent drought	2,461,176	16.12	36.77	433,187	15.26	35.96
Percent Hindu	.	.	.	432,801	75.03	43.29

Note: Table shows summary statistics for the main Sub-Saharan Africa (SSA) and India regression samples, consisting of women aged 25 or older at the time of interview. Summary statistics for SSA are weighted by the population-adjusted survey sampling weights.

Table A3: List of Main Datasets and Sources

Region/ Country	Data Topic	Source	Years
Sub-Saharan Africa	Crop Yield	FAOStat database	1960-2010
	Conflict	UCDP/PRIO Armed Conflict Dataset	1946-2015
	GDP per capita	World Bank WDI	1961-2010
	Consumption	World Bank WDI	1961-2010
	Marriage	Demographic and Health Survey (DHS)	1994-2014
India	Crop Yield	World Bank India Agriculture and Climate Data Set	1957-1987
	NSDP per capita	EPW Research Foundation India Time Series	1961-1989
	Consumption	National Social Survey (NSS)	1994-1998
	Marriage	Demographic and Health Survey (DHS)	1998-1999
	Marriage and migration	India Human Development Survey (IHDS)	2005
	Dowry	Rural Economic and Demographic Survey (REDS)	1998
	Irrigation	ICRISAT	1966-2011
	Credit markets	Jayachandran (2006)	1960-1999
	Sex ratios	Census of India	1961-2001
Indonesia	Bride price	Indonesia Family Life Survey (IFLS)	2000, 2007
	Marriage	Intercensal Population Surveys (SUPAS)	1995
	Rainfall	University of Delaware (UDel)	1950-2010
	Population	World Development Indicators (WDI)	1990-2012
	Ethnic information	Atlas of Pre-colonial societies (ATLAS)	

Table A4: List of Waves Used for DHS Africa

Country	Waves
Benin	1996, 2001, 2011-12
Burkina Faso	1998-99, 2003, 2010
Burundi	2010
Cameroon	2004, 2011
CAR	1994-95, 2013-14
Congo DR	2007
Cote D'Ivoire	1994, 1998-99, 2011-12
Ethiopia	2000, 2005, 2011
Gabon	2012
Ghana	1998, 2003, 2008, 2014
Guinea	1999, 2005, 2012
Kenya	2003, 2008-09, 2014
Lesotho	2004, 2009, 2014
Liberia	2007, 2013
Madagascar	1997, 2008-09
Malawi	2000, 2004, 2010
Mali	1995-96, 2001, 2006, 2012-13
Mozambique	2011
Namibia	2000, 2006-07, 2013
Niger	1998
Nigeria	2003, 2008, 2013
Rwanda	2005, 2010, 2014-15
Senegal	1997, 2005, 2010-11
Sierra Leone	2008, 2013
Swaziland	2006-07
Tanzania	1999, 2010
Togo	1998, 2013-14
Uganda	2000-01, 2006, 2011
Zambia	2007, 2013-14
Zimbabwe	1999, 2005-06, 2010-11

Table A5: Timing of major conflict in our SSA sample

Country	conflict period	Country	conflict period
Burundi	1994-2006	Nigeria	1967-1970
Cameroon	1960-1961	Rwanda	1990-1994
Congo DR	1964-1965		1996-2002
	1996-2001	Sierra Leone	1991-2001
Ethiopia	1964-1991	Uganda	1979-1992
Kenya	1952-1956		1994-2011
Liberia	2000-2003	Zimbabwe	1973-1979
Mozambique	1964-1974		
	1977-1992		

Note: Data from UCDP/PRIO Armed Conflict Dataset.

Table A6: Marriage migration in Africa and in India

Panel A: Data from DHS				
	Never migrated	Migrated before marriage	Migrated at marriage	Migrated after marriage
SSA	41.04%	7.39%	22.96%	28.61%
India	13.21%	9.16%	58.02%	19.62%
Panel B: Data from IHDS				
	Distance to wife's natal home (hrs)			
	Mean	Median	75th percentile	90th percentile
India	3.44	2.00	4.00	6.00

Note: Panel A shows how long ever-married women have lived in their current place of residence (village, town or city where she is interviewed). *Migrated at marriage* includes women who report migrating to their current place of residence within one year of getting married.

Table A7: Marriage migration patterns by rainfall realization at the time of marriage

	SSA		India: DHS	India: IHDS	
	(1)	(2)	(3)	(4)	(5)
	born here	marr. migr.	marr. migr.	same village	distance
Drought	0.00070	-0.0016	-0.0071	0.0017	-0.090
	(0.0059)	(0.0048)	(0.0057)	(0.0063)	(0.11)
Birth Year FE	Yes	Yes	Yes	Yes	Yes
Marriage Year FE	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	No	No	No
N	179,542	176,498	60,802	25,442	25,245
Adjusted R^2	0.16	0.10	0.17	0.12	0.062
Mean of Dep. Var.	0.41	0.17	0.14	0.14	3.42

Note: * p<0.1, ** p<0.05, *** p<0.01
Results for SSA and India full regression samples up to age 24. Standard errors (in parentheses) are clustered at the grid cell level (for SSA) and district level (for India). All regression specifications include grid cell fixed effects or district fixed effects. A drought is defined as an annual rainfall realization below the 15th percentile of the local rainfall distribution. Regressions for SSA are weighted by population-adjusted survey sampling weights.

Table A8: Effect of drought on child marriage, by ethnic characteristics in SSA

	(1)	(2)	(3)	(4)
Drought × bride price	0.0024*	0.0028*	0.0030**	
	(0.0013)	(0.0015)	(0.0014)	
Drought × no bride price	-0.00059	0.0000092	0.00097	
	(0.0022)	(0.0025)	(0.0027)	
Drought × female agriculture		-0.0012		
		(0.0023)		
Drought × matrilineal			-0.0027	
			(0.0024)	
Drought × (BP & not matri.)				0.0030**
				(0.0014)
Drought × (no BP & matri.)				-0.0016
				(0.0027)
Drought × (BP & matri.)				0.00022
				(0.0025)
Drought × (no BP & not matri.)				0.00075
				(0.0036)
Interacted Birth Year FE	Yes	Yes	Yes	Yes
Interacted Age FE	Yes	Yes	Yes	Yes
N	1,260,930	1,260,930	1,260,930	1,260,930
Adjusted R^2	0.074	0.076	0.074	0.074

Note: * $p<0.1$, ** $p<0.05$, *** $p<0.01$ Table shows OLS regressions for the Sub-Saharan Africa (SSA) full regression samples: women aged 25 or older at the time of interview. Observations are at the level of person × age (from 12 to or age of marriage, whichever is earlier). The dependent variable is a binary variable for marriage, coded to one if the woman married at the age corresponding to the observation. The p-value of the Wald test of equality between Drought × bride price and Drought × no bride price in Specification 1 is 0.245. For Specification 2, it is 0.279. For Specification 3, it is 0.463. Standard errors (in parentheses) are clustered at the grid cell level. A drought is defined as an annual rainfall realization below the 15th percentile of the local rainfall distribution. All regression specifications include grid cell fixed effects. Regressions are weighted by population-adjusted survey sampling weights.

Table A9: Effect of Weather Shocks on the Timing of Fertility in Sub-Saharan-Africa and India

	SSA			India	
	(1)	(2)	(3)	(4)	(5)
Drought	0.0034***	0.0034***	0.0030***	-0.00052	-0.00037
	(0.00099)	(0.00099)	(0.00098)	(0.0011)	(0.0011)
Birth Year FE	Yes	Yes	Yes	Yes	Yes
Age FE	Yes	Yes	Yes	Yes	Yes
Country FE	No	Yes	Yes	No	No
Country FE × Cohort FE	No	No	Yes	No	No
State FE × Cohort FE	No	No	No	No	Yes
N	2,754,577	2,754,577	2,754,577	560,616	560,616
Adjusted R^2	0.064	0.064	0.064	0.080	0.080

Note: * p<0.1, ** p<0.05, *** p<0.01
Table shows OLS regressions for Sub-Saharan Africa (SSA) and India: women aged 25 or older at the time of interview. Observations are at the level of person × age (from 12 to 24 or age of first birth, whichever is earlier). The dependent variable is a binary variable for fertility, coded to one if the woman had her first child at the age corresponding to the observation. Standard errors (in parentheses) are clustered at the grid cell level (in SSA) and district level (India) . All regression specifications include grid cell fixed effects (in SSA) and district level fixed effects (in India). A drought is defined as an annual rainfall realization below the 15th percentile of the local rainfall distribution. Results are weighted by population-adjusted survey sampling weights.

Table A10: Long-run effects of drought in SSA and India

	SSA		India	
	Child marriage	Births by 25	Child marriage	Births by 25
Any drought ages 12-14	0.0042	0.024*	0.0019	-0.0048
	(0.0035)	(0.014)	(0.0043)	(0.015)
Any drought ages 15-17	0.0088***	0.055***	-0.0096**	-0.017
	(0.0034)	(0.013)	(0.0041)	(0.013)
Birth Year FE	Yes	Yes	Yes	Yes
Current Age FE	Yes	Yes	No	No
Country FE	Yes	Yes	No	No
N	344,727	344,727	66,466	66,466
Adjusted R^2	0.17	0.15	0.18	0.10

Note: * p<0.1, ** p<0.05, *** p<0.01 Table shows OLS cross-sectional regressions for Sub-Saharan Africa (SSA) and India full regression samples: women aged 25 or older at the time of interview. Standard errors (in parentheses) are clustered at the grid cell or district level. A drought is defined as an annual rainfall realization below the 15th percentile of the local rainfall distribution. All regression specifications include grid cell or district fixed effects. Results are weighted using population-adjusted survey sampling weights.

Table A11: Effect of droughts on school dropout

	All SSA		India	
	(1)	(2)	(3)	(4)
Drought at t or $t+1$ or $t-1$	0.0043***		-0.000047	
	(0.0016)		(0.0013)	
Drought × <12 y.o.		0.0027*		0.0027*
		(0.0015)		(0.0016)
Drought × ≥12 y.o.		0.0072**		-0.0053
		(0.0036)		(0.0033)
Birth Year FE	Yes	Yes	Yes	Yes
Age FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	No	No
N	1,440,348	1,440,348	271,056	271,056
Adjusted R^2	0.11	0.11	0.11	0.11

Note: * p<0.1, ** p<0.05, *** p<0.01
Table shows OLS regression for all SSA, and India full regression samples: women aged 25 or older at the time of interview. Observations are at the level of person × age (from 6 to 17 or school dropout, whichever is earlier). The dependent variable is a binary variable for school dropout, coded to one if the woman dropped out of school at the age corresponding to the observation. Standard errors (in parentheses) are clustered at the district level. A drought is defined as an annual rainfall realization below the 15th percentile of the local rainfall distribution. All regression specifications include district fixed effects.

Table A12: Marriage Characteristics by Rainfall Realization at the Time of Marriage

	SSA						India			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	no edu	husb no edu	age gap	polygyny	wife rank	no say	no edu	husb no edu	age gap	no say
Drought	0.0122***	0.0002	-0.2378*	0.0086	-0.0221*	0.0517**	0.0044	0.0013	0.1121	-0.0254
	(0.0039)	(0.0051)	(0.1278)	(0.0072)	(0.0132)	(0.0219)	(0.0065)	(0.0018)	(0.0903)	(0.0189)
Birth Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Marriage Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No
N	275,667	133,027	120,769	123,233	45,778	145,984	35,932	23,128	32,982	35,942
Adjusted R^2	0.49	0.47	0.15	0.17	0.04	0.39	0.16	0.02	0.08	0.12
Mean of Dep. Var.	0.490	0.525	11.109	0.389	0.515	1.354	0.651	0.008	6.753	1.217

Note: * p<0.1, ** p<0.05, *** p<0.01
Results for SSA countries with high prevalence of bride price (BP) custom and India. Robust standard errors (in parentheses) are clustered at the grid cell (SSA) or district level (India). All regression specifications include grid cell (SSA) or district (India) fixed effects. Results for SSA are weighted by country population-adjusted survey sampling weights.

Table A13: Marriage Characteristics by Rainfall Realization at the Time of Marriage in India: Combining DHS and IHDS

	(1)	(2)	(3)	(4)
	no edu	husb no edu	age gap	no say
Drought	-0.016*	-0.0010	0.13*	-0.012*
	(0.0090)	(0.0100)	(0.077)	(0.0066)
Birth Year FE	Yes	Yes	Yes	Yes
Marriage Year FE	Yes	Yes	Yes	Yes
N	50,100	36,070	45,990	50,180
Adjusted R^2	0.15	0.16	0.11	0.26
Mean of Dep. Var.	0.63	0.099	6.41	0.42

Note: * p<0.1, ** p<0.05, *** p<0.01
Results use both the India DHS from 1998 and the IHDS from 2004-2005. Standard errors (in parentheses) are clustered at thedistrict level (India). A drought is defined as an annual rainfall realization below the 15th percentile of the local rainfall distribution. All regression specifications include grid cell (SSA) or district (India) fixed effects. Results for SSA are weighted by population-adjusted survey sampling weights.

Table A14: Association Between Rainfall Levels and Child Marriage

	SSA			India	
	(1)	(2)	(3)	(4)	(5)
Log(Rainfall)	-0.0046**	-0.0045**	-0.0035	0.0039*	0.0041*
	(0.0021)	(0.0021)	(0.0022)	(0.0023)	(0.0024)
Birth Year FE	Yes	Yes	Yes	Yes	Yes
Age FE	Yes	Yes	Yes	Yes	Yes
Country FE	No	Yes	Yes	No	No
Country FE × Cohort FE	No	No	Yes	No	No
State FE × Cohort FE	No	No	No	No	Yes
N	1,799,037	1,799,037	1,799,037	329,586	329,586
Adjusted R^2	0.071	0.072	0.072	0.082	0.082

Note: * p<0.1, ** p<0.05, *** p<0.01
Table shows OLS regressions for the Sub-Saharan Africa (SSA) and India full regression samples: women aged 25 or older at the time of interview. Observations are at the level of person × age (from 12 to 17 or age of first marriage, whichever is earlier). The dependent variable is a binary variable for marriage, coded to one if the woman married at the age corresponding to the observation. Standard errors (in parentheses) are clustered at the grid cell level (SSA) or district level (India). A drought is defined as an annual rainfall realization below the 15th percentile of the local rainfall distribution. All regression specifications include grid cell (SSA) or district (India) fixed effects. Regressions for SSA are weighted using population-adjusted survey sampling weights.

Table A15: Effect of Droughts and Floods on Child Marriage

	SSA		India	
	(1)	(2)	(3)	(4)
Drought	0.0024**	0.0024**	-0.0054***	-0.012***
	(0.0012)	(0.0012)	(0.0016)	(0.0036)
Flood	-0.0016	-0.0017	-0.0046***	-0.011***
	(0.0014)	(0.0014)	(0.0015)	(0.0035)
Drought × Rice share				0.0048
				(0.0059)
Flood × Rice share				0.013**
				(0.0061)
Birth Year FE	Yes	Yes	Yes	Yes
Age FE	Yes	Yes	Yes	Yes
Country FE	No	Yes	No	No
N	1,799,037	1,799,037	329,586	175,707
Adjusted R^2	0.071	0.072	0.082	0.082

Note: * p<0.1, ** p<0.05, *** p<0.01
Table shows OLS regressions for SSA and India: women aged 25 or older at the time of interview. Observations are at the level of person × age (from 12 to 17 or age of first marriage, whichever is earlier). The dependent variable is a binary variable for marriage, coded to one if the woman married at the age corresponding to the observation. Standard errors (in parentheses) are clustered at the grid cell level (SSA) or district level (India). Rice cultivation data is from the World Bank India Agriculture and Climate Dataset. A drought is defined as an annual rainfall realization below the 15th percentile of the local rainfall distribution. All regression specifications include grid cell fixed effects (SSA) or district fixed effects (India). Regressions for SSA are weighted by population-adjusted survey sampling weights.

Table A16: Effect of Rainfall Shocks by Quintile on the Timing of Marriage

	(1)	(2)
	SSA	India
Bottom Quintile	0.0019*	-0.0045***
	(0.0010)	(0.0013)
Birth Year FE	Yes	Yes
Age FE	Yes	Yes
Country FE	Yes	No
N	1,799,034	329,586
Adjusted R^2	0.072	0.082

Note: * p<0.1, ** p<0.05, *** p<0.01
Table shows OLS regressions for the Sub-Saharan Africa (SSA) and India full regression samples: women aged 25 or older at the time of interview. Observations are at the level of person × age (from 12 to 17 or age of first marriage, whichever is earlier). The dependent variable is a binary variable for marriage, coded to one if the woman married at the age corresponding to the observation. Standard errors (in parentheses) are clustered at the grid cell level (SSA) or district level (India). A drought is defined as an annual rainfall realization below the 15th percentile of the local rainfall distribution. All regression specifications include grid cell (SSA) or district (India) fixed effects. The regression for SSA is weighted using population-adjusted survey sampling weights.

Table A17: Current, Lag, and Future Droughts and the Timing of Marriage

	SSA			India			SSA as India	India as SSA
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Drought	0.0026**	0.0026**		-0.0048***	-0.0048***			
	(0.0012)	(0.0012)		(0.0016)	(0.0016)			
Drought Lag 1	-0.000079	-0.000031		-0.0041***	-0.0041***		-0.000066	
	(0.0012)	(0.0012)		(0.0015)	(0.0015)		(0.0012)	
Drought Lead 1		0.0013			-0.000076			0.00031
		(0.0012)			(0.0015)			(0.0015)
Any Drought in Current & Last & Next Years			0.0028***			-0.0045***		
			(0.00095)			(0.0013)		
Birth Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Age FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	No	No	No	Yes	No
N	1,799,037	1,799,037	1,799,037	329,586	329,586	329,586	1,799,037	329,586
Adjusted R^2	0.072	0.072	0.072	0.082	0.082	0.082	0.072	0.082

Note: * p<0.1, ** p<0.05, *** p<0.01
Table shows OLS regressions for the Sub-Saharan Africa (SSA) and India full regression samples: women aged 25 or older at the time of interview. Observations are at the level of person $\times$ age (from 12 to 17 or age of first marriage, whichever is earlier). The dependent variable is a binary variable for marriage, coded to one if the woman married at the age corresponding to the observation. Standard errors (in parentheses) are clustered at the grid cell level (SSA) or district level (India). A drought is defined as an annual rainfall realization below the 15th percentile of the local rainfall distribution. All regression specifications include grid cell (SSA) or district (India) fixed effects. Regressions for SSA are weighted using population-adjusted survey sampling weights.

Table A18: Robustness of Effect of Drought on Early Marriage to Specification and Sample

	SSA		
	(1)	(2)	(3)
	No Survey Weights	Most Recent Wave per Country	Drop Never Married
Drought	0.0015**	0.0028**	0.0025**
	(0.00063)	(0.0013)	(0.0012)
Birth Year FE	Yes	Yes	Yes
Age FE	Yes	Yes	Yes
Country FE	Yes	Yes	Yes
N	1,803,690	946,499	1,672,431
Adjusted R^2	0.065	0.067	0.072

Note: * p<0.1, ** p<0.05, *** p<0.01
Table shows OLS regressions with different weight and sample specifications for the Sub-Saharan Africa (SSA) full regression sample: women aged 25 or older at the time of interview. Observations are at the level of person $\times$ age (from 12 to 17 or age of first marriage, whichever is earlier). The dependent variable is a binary variable for marriage, coded to one if the woman married at the age corresponding to the observation. Standard errors (in parentheses) are clustered at the grid cell level. A drought is defined as an annual rainfall realization below the 15th percentile of the local rainfall distribution. All regression specifications include grid cell fixed effects. Results are weighted using population-adjusted survey sampling weights.

Table A19: Effect of Drought on Marriage in SSA, Including Conflict Observations

	Timing of marriage		Child marriage	
	(1)	(2)	(3)	(4)
Drought × war	-0.0035		-0.0039*	
	(0.0021)		(0.0023)	
Drought × no war	0.0038***		0.0028**	
	(0.0012)		(0.0012)	
Drought		0.0019*		0.0011
		(0.0011)		(0.0011)
Birth year FE	No	Yes	No	Yes
War × birth year FE	Yes	No	Yes	No
Age FE	No	Yes	No	Yes
War × age FE	Yes	No	Yes	No
Country FE	Yes	Yes	Yes	Yes
N	3,190,923	3,190,923	2,200,995	2,200,995
Adjusted R^2	0.061	0.061	0.072	0.071

Note: * p<0.1, ** p<0.05, *** p<0.01 Table shows OLS regressions for Sub-Saharan Africa (SSA): women aged 25 or older at the time of interview, including those exposed to war. Observations are at the level of person × age (from 12 to upper age limit or age of first marriage, whichever is earlier). The upper age limit is 24 for "Timing of marriage" regressions and 17 for "Early marriage" regressions. The dependent variable is a binary variable for marriage, coded to one if the woman married at the age corresponding to the observation. In column 1, the p-value of the test of equality between the coefficient on Drought × war and Drought × no war is 0.0020. In column 3, it is 0.010. Standard errors (in parentheses) are clustered at the grid cell level. All regression specifications include grid cell fixed effects. A drought is defined as an annual rainfall realization below the 15th percentile of the local rainfall distribution. Results are weighted using population-adjusted survey sampling weights.

Table A20: Effect of Drought on the Timing of Marriage in India: DHS and IHDS Data

	DHS		IHDS		DHS and IHDS	
	(1)	(2)	(3)	(4)	(5)	(6)
Drought	-0.0046***	-0.0047***	-0.0085***	-0.0085***	-0.0097***	-0.010***
	(0.0016)	(0.0017)	(0.0023)	(0.0022)	(0.0023)	(0.0024)
Birth Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Age FE	Yes	Yes	Yes	Yes	Yes	Yes
State FE × Cohort FE	No	Yes	No	Yes	No	Yes
N	329,586	329,586	133,942	133,942	463,528	463,528
Adjusted R^2	0.082	0.082	0.088	0.089	0.085	0.085

Note: * p<0.1, ** p<0.05, *** p<0.01
Table shows OLS regressions using DHS and IHDS surveys in India. Each regression sample consists of women aged 25 or older at the time of interview. Observations are at the level of person × age (from 12 to 17 or age of first marriage, whichever is earlier). The dependent variable is a binary variable for marriage, coded to one if the woman married at the age corresponding to the observation. Standard errors (in parentheses) are clustered at the district level. A drought is defined as an annual rainfall realization below the 15th percentile of the local rainfall distribution. All regression specifications include district fixed effects. Regressions in columns 5 and 6 are weighted using population-adjusted survey sampling weights.

Table A21: Weather shocks, crop yields, and income in India, with Heterogeneity

	(1) Crop Yields	(2) HH cons.	(3) HH cons.
Drought × Low Irrig	-0.225***	-0.037**	
	(0.02)	(0.02)	
Drought × High Irrig	-0.074***	-0.019	
	(0.02)	(0.02)	
Drought × Low Banking			-0.055***
			(0.02)
Drought × High Banking			0.021
			(0.03)
N	5,936	132,293	119,253
Adjusted R^2	0.78	0.21	0.21

Note: * p<0.1, ** p<0.05, *** p<0.01
The dependent variable is described above each column. Crop yield data (measured in tons) are from FAOStat; HH consumption data (2011 INR) are from the NSS. The dependent variable for "Crop Yields" is the log of the sum of total production of main crops reported (maize, sorghum, millet, rice, and wheat) divided by the total area harvested for those crops. The measure of high and low banking in column 3 is created using bank branches per capita. In column 1, the p-value of the test of equality between Drought × low irrigation and Drought × high irrigation is 0.000. In column 2, it is 0.451. In column 3, the p-value for Drought × low banking and Drought × high banking is 0.020. Robust standard errors (in parentheses) are clustered at the state level. All regression specifications include year×low-irrigation or year×low-banking and state fixed effects (district fixed effects for HH consumption specifications).

Table A22: Effect of Drought on the Timing of Marriage in India by Irrigation Intensity and Bank Development

	(1)	(2)	(3)	(4)
Drought × Low Irrig	-0.0060**			
	(0.0026)			
Drought × High Irrig	0.0016			
	(0.0028)			
Drought × Low Banking		-0.0057**	-0.0058**	-0.0055**
		(0.0026)	(0.0025)	(0.0024)
Drought × High Banking		-0.0028	-0.0029	-0.0031
		(0.0019)	(0.0019)	(0.0020)
Birth Year FE × High Banking FE	No	Yes	Yes	Yes
Age FE × High Banking FE	No	Yes	Yes	Yes
Birth Year FE × High Irrig FE	Yes	No	No	No
Age FE × High Irrig FE	Yes	No	No	No
N	247,038	329,586	329,586	329,586
Adjusted R^2	0.084	0.085	0.085	0.085

Note: * p<0.1, ** p<0.05, *** p<0.01
Table shows OLS regressions using additional surveys in India. Each regression sample consists of women aged 25 or older at the time of interview. Deposits and credit per capita are as measured in 1981. The irrigation or banking variable used in each regression is specified at the top of each column. Observations are at the level of person × age (from 12 to 17 or age of first marriage, whichever is earlier). The dependent variable is a binary variable for marriage, coded to one if the woman married at the age corresponding to the observation. The p-value of the Wald test of equality between Drought × Low Irrigation and Drought × High Irrigation is 0.047. For Low Deposits and High Deposits, it is 0.363. For Low Credit and High Credit, it is 0.362. For Low Banks and High Banks, it is 0.441. Standard errors (in parentheses) are clustered at the district level. A drought is defined as an annual rainfall realization below the 15th percentile of the local rainfall distribution. All regression specifications include district fixed effects.

Table A23: Effect of drought on marriage in SSA, by household composition with BP $\geq$ 50%

	(1)	(2)	(3)	(4)
Drought	0.0054**	0.0054**	0.0037**	0.0064***
	(0.0026)	(0.0026)	(0.0015)	(0.0023)
Drought × siblings	-0.00062			
	(0.00045)			
Drought × brothers		-0.00064		
		(0.00062)		
Drought × sisters		-0.00062		
		(0.00065)		
Drought × (4+ brothers)			-0.0041*	
			(0.0024)	
			{0.85}	
Drought × (4+ sisters)			-0.0014	
			(0.0024)	
			{0.31}	
Drought × (>1 older brother)				-0.0039
				(0.0026)
				{0.37}
Drought × (>1 older sister)				0.000037
				(0.0026)
				{0.014}
Drought × (>1 younger brother)				-0.0038
				(0.0026)
				{0.29}
Drought × (>1 younger sister)				-0.0027
				(0.0026)
				{0.23}
Interacted birth year FE	Yes	Yes	Yes	Yes
Interacted age FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
No. of brothers FE	No	No	Yes	Yes
No. of sisters FE	No	No	Yes	Yes
N	1,208,119	1,208,119	1,208,119	1,208,119
Adjusted R^2	0.074	0.074	0.074	0.074

Note: * p<0.1, ** p<0.05, *** p<0.01 Table shows OLS regressions for the Sub-Saharan Africa (SSA) full regression samples for countries with $\geq$ 50% BP: women aged 25 or older at the time of interview. Observations are at the level of person × age (from 12 to or age of marriage, whichever is earlier). The dependent variable is a binary variable for marriage, coded to one if the woman married at the age corresponding to the observation. Information on siblings is available in all surveys except the following: Benin 2001 and 2012, Cote d'Ivoire 1998, Eritrea 2002, Ghana 1998, 2003, 2008, and 2014, Niger 1998, Nigeria 2003, Senegal 1997, and Tanzania 1999. Birth year and age FE are interacted with the same variable(s) as the drought interaction in each specification. Standard errors (in parentheses) are clustered at the grid cell level. P-values for the additive effect of drought are displayed in braces. A drought is defined as an annual rainfall realization below the 15th percentile of the local rainfall distribution. All regression specifications include grid cell fixed effects.

Table A24: Heterogeneity in the effect of drought on the timing of marriage by district-level sex ratio in India

	(1) State	(2) District	(3) State	(4) District
Drought	-0.0047***	-0.0046***	-0.0033	-0.0045*
	(0.0016)	(0.0016)	(0.0024)	(0.0025)
Drought × de-meaned sex ratio	0.000083	-0.00015		
	(0.00034)	(0.00017)		
Drought × (< 85F/100M)			-0.015***	0.0047
			(0.0042)	(0.0044)
			{0.000}	{0.969}
Drought × (85-95F/100M)			-0.00061	-0.0013
			(0.0033)	(0.0035)
			{0.079}	{0.020}
Birth Year FE	Yes	Yes	Yes	Yes
Age FE	Yes	Yes	Yes	Yes
Interacted birth year FE	Yes	Yes	Yes	Yes
Interacted age FE	Yes	Yes	Yes	Yes
N	329,586	329,586	329,586	329,586
Adjusted R^2	0.082	0.082	0.083	0.082

Note: * p<0.1, ** p<0.05, *** p<0.01
Table shows OLS regressions for the India full regression samples: women aged 25 or older at the time of interview. The number in braces is the p-value of the total additive effect of drought within the corresponding group. Observations are at the level of person × age (from 12 to 17 or age of first marriage, whichever is earlier). The dependent variable is a binary variable for marriage, coded to one if the woman married at the age corresponding to the observation. The state-level and district-level sex ratios are taken from the Indian census data between 1961 and 2001 and linearly interpolated/extrapolated for years not in the census. In columns 1 and 2, birth year and age FE are interacted with the continuous sex ratio variable. Standard errors (in parentheses) are clustered at the district level. A drought is defined as an annual rainfall realization below the 15th percentile of the local rainfall distribution. All regression specifications include district fixed effects.

Table A25: Effect of drought on early marriages in Indonesia

	IFLS		SUPAS	
	(1)	(2)	(3)	(4)
Drought	0.0054	0.0061	0.019***	0.018**
	(0.0032)	(0.0032)	(0.0041)	(0.0041)
	[0.124]	[0.152]	[0.000]	[0.036]
Birth Year FE	Yes	Yes	Yes	Yes
Age FE	Yes	Yes	Yes	Yes
Province FE	Yes	No	Yes	No
Province FE $\times$ Cohort FE	No	Yes	No	Yes
N	64,998	64,998	308,112	308,112
Clusters	25	25	18	18
Adjusted R^2	0.029	0.029	0.038	0.039

Note: * p<0.1, ** p<0.05, *** p<0.01 Table shows OLS regressions for the Indonesian IFLS and SUPAS full regression samples: women aged 17 or older at the time of interview. Observations are at the level of person $\times$ age (from 12 to 17 or age of first marriage, whichever is earlier). The dependent variable is a binary variable for marriage, coded to one if the woman married at the age corresponding to the observation. A drought is defined as an annual rainfall realization below the 15th percentile of the local rainfall distribution. Standard errors (in parentheses) are clustered at the province level. Wild bootstrap p-values are displayed in brackets.

Table A26: P-values for alternative clustering methods for table 4

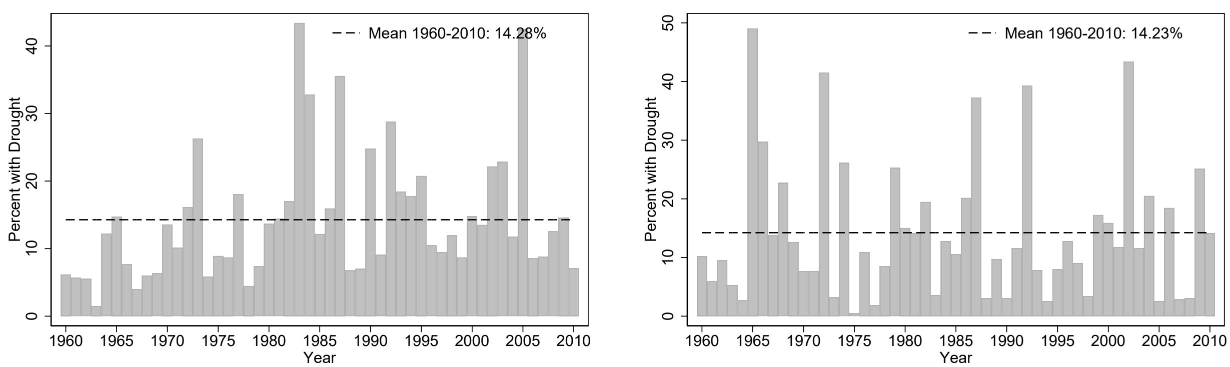
SSA DHS			
	cluster at grid level	cluster at country level	
Column 1	0.027	0.006	
Column 2	0.029	0.008	
Column 3	0.099	0.025	
India DHS			
	cluster at district level	cluster at state level	wild-bootstrap cluster at state level
Column 4	0.005	0.009	0.008
Column 5	0.005	0.008	0.016

Note: * p<0.1, ** p<0.05, *** p<0.01
Table shows p-values for OLS regressions reported in table 4 for the Sub-Saharan Africa (SSA) and India full regression samples: women aged 25 or older at the time of interview. Observations are at the level of person $\times$ age (from 12 to 17 or age of first marriage, whichever is earlier). The dependent variable is a binary variable for marriage, coded to one if the woman married at the age corresponding to the observation. All regression specifications include grid cell (SSA) or district (India) fixed effects. A drought is defined as an annual rainfall realization below the 15th percentile of the local rainfall distribution. Regressions for SSA are weighted using population-adjusted survey sampling weights.

Table A27: Matching to ATLAS in SSA Regression Sample

	Freq.	Pct.	Cum. Pct.
Panel A: All Individuals			
Matched	239,359	73.28	73.28
Unmatched	1,494	0.46	73.74
Other ethnicity	17,924	5.49	79.22
Missing ethnicity	67,868	20.78	100.00
Total	326,645	100.00	.
Panel B: With valid ethnic entry			
Verbatim match	138,136	57.35	57.35
Wikipedia	63,908	26.53	83.89
Ethnologue	17,115	7.11	90.99
Joshua Project	14,171	5.88	96.88
Africaans to Afrikaans	545	0.23	97.10
Other website	5,484	2.28	99.38
Unmatched	1,494	0.62	100.00
Total	240,853	100.00	.

Figure A1: Prevalence of Drought in Sub-Saharan Africa and India by Year

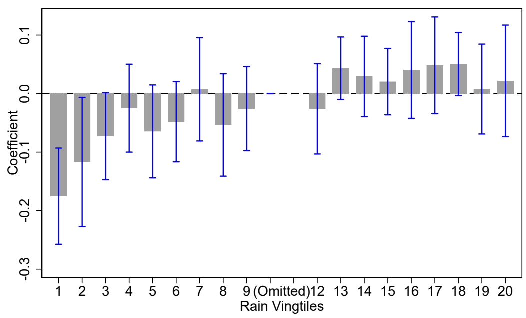


(a) SSA

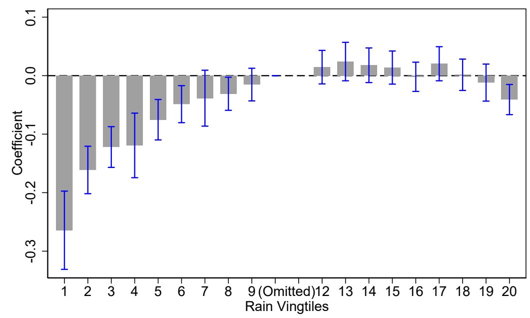
(b) India

Note: Figures shows the prevalence of drought in Sub-Saharan Africa (SSA) and India, presented as the percentage of grid cells (SSA) or districts (India) with drought in each calendar year. For all the analyses in this paper, for any grid cell or district, we define a drought as having rainfall lower than the 15$^{\text{th}}$ percentile of the long-run rainfall distribution. The black dashed line shows the mean of drought in each sub-figure from 1950-2010.

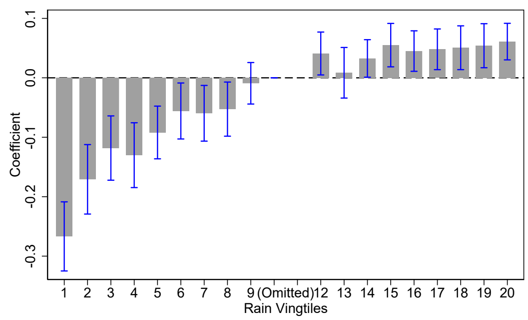
Figure A2: Crop Yields and Rainfall Vingtiles in Sub-Saharan Africa and India



(a) SSA: Average for Main Crops



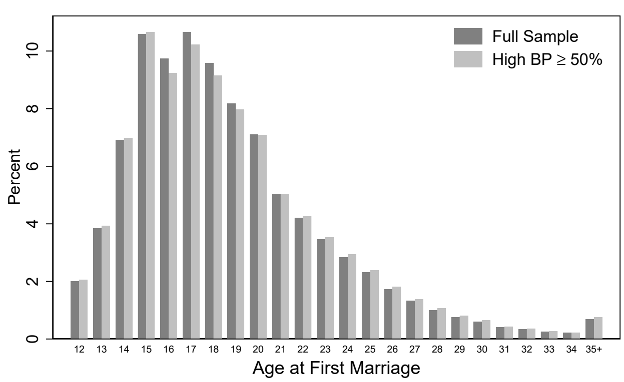
(b) India: Average for Main Crops



(c) India: Rice

Note: Figure a plots the coefficients of rainfall vingtiles in regressions with log of annual crop yield (tons per hectare) from 1961 to 2010 as the dependent variable in SSA. Figure b plots the coefficients of rainfall vingtiles in regressions with log of annual crop yield (tons per hectare) for Indian districts from 1957 to 1987 as the dependent variable. All regression specifications include year and country or district fixed effects. The capped vertical bars show 95% confidence intervals calculated using robust standard errors clustered at the country level.

Figure A3: Distribution of the Ages at First Marriage

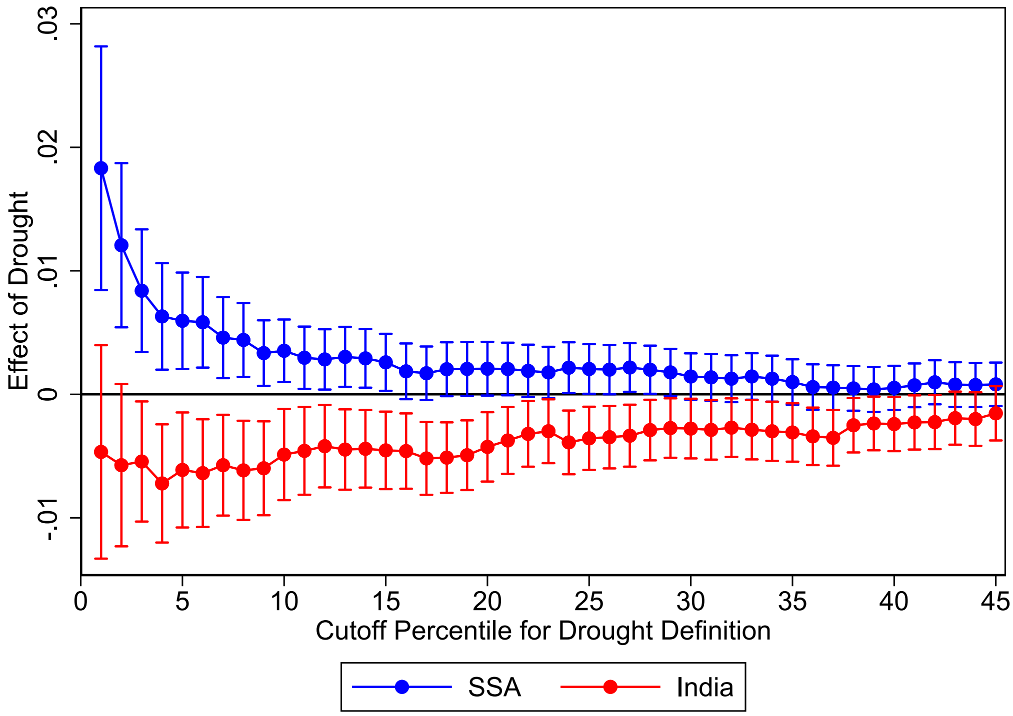


(a) SSA

(b) India

Note: Figures show the distribution of ages at first marriage for individuals in our main analysis samples: surveyed women aged 25 or above at the time of interview. Those who were not married are not shown as a separate category in these plots, but they were included in the denominator of the calculation of these percentages.

Figure A4: Robustness in the Definition of Drought Based on Cutoffs in Rainfall Distribution



Note: Figure shows the point estimates of the Effect of Droughts on early marriages, estimated using OLS regressions for the Sub-Saharan Africa (SSA) and India full regression samples: women aged 25 or older at the time of interview. The different points represent different definitions of drought based on the percentile of rainfall in a grid cell (SSA) or district (India) in a given year, relative to the fitted long run rainfall (gamma) distribution in that grid cell or district. The capped spikes show the 95% confidence intervals of the estimated coefficients. For all the analyses in this paper, for any grid cell or district, we define a drought as having rainfall lower than the 15^{th} percentile of the long-run rainfall distribution.