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

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Abstract

Cultural norms play an important role in influencing economic behavior and can shape households' decisions even in response to the same economic circumstances. For this reason, they may determine the external validity of the empirical findings from natural experiments. This paper examines the effect of local rainfall shocks on female child marriages in sub-Saharan Africa and in India. We show that droughts have similar negative effects on crop yields, but opposite effects on child marriage in the two regions: in Africa, droughts increase the probability of child marriage, while in India droughts decrease such a probability. To explain this outcome, we develop a simple equilibrium model of the marriage market in which income shocks affect the timing of marriage because the transfers that traditionally occur at the time of marriage are a source of consumption smoothing, particularly for a woman's family. Exploiting heterogeneity in the marriage payment traditions across countries and ethnic groups, and additional data from Indonesia, we argue that the differential impact of drought on the marriage hazard that we document is explained by differences in the direction of traditional marriage payments in each region, bride price across sub-Saharan Africa and Indonesia and dowry in India.

JEL Codes: J1, O15.

Keywords: Income shocks, informal insurance, marriage, Africa, India, dowry, bride price

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1 Introduction

Social scientists have now well recognized the important role of cultural and traditional norms in shaping economic behavior both in developed and in developing countries. Recent studies have also shown that social norms can contribute to the effectiveness of development policies, and there have been increasing calls by international organizations, such as the World Bank and the United Nations, for improving the tailoring of interventions to the local context.[1] In this paper, we argue that cultural norms may also influence the external validity of the empirical findings from natural experiments, by radically modifying the economic relationship between variables, and hence that understanding their role can contribute to policy design and evaluation. In particular, we examine the determinants of female child marriage, a widespread and dramatic phenomenon in the developing world, and we find that understanding how economic forces influence it requires also understanding how the local cultural norms work.

Despite improvements in female educational and economic opportunities, large numbers of young women continue to marry at an early age. Worldwide, more than 700 million women alive today were married before their 18th birthday and 25 million entered into union before age 15 (UNICEF, 2014). Child marriage (defined as marriage before the age of 18) is especially pronounced among women living in sub-Saharan Africa and South Asia, where more than 50% of women continue to marry before age 18, and 20% marry before age 15.[2] Because of the strong association between child marriage and poverty worldwide, it is natural to ask whether experiencing negative economic shocks increase the risk that a woman marries before turning 18.

To shed light on this question, we examine the effect of rainfall shocks –a major source of income variability in rural areas that rely on rain-fed agriculture– on the probability of early marriage among young women in two regions of the world, 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 data from sixty pooled Demographic and Health Surveys (DHS) for thirty sub-Saharan African countries between 1994 and 2013, from

[1]The most recent World Development Report focuses on the idea that "paying attention to how humans think (the processes of mind) and how history and context shape thinking (the influence of the society) can improve the design and the implementation of development policies that target human choice and action (behavior)" (World Bank, 2015).

[2]Figures are based on DHS surveys for India (2005) and Africa (2006-2012), considering women aged 20-24 living in rural areas. See table A2 for the African countries included in the analysis.

the 1998-1999 DHS of India, and the 2005 Indian Human Development Survey (IHDS). We obtain information on the age of marriage and on the history of rainfall shocks of approximately 450,000 women for every year between age ten and age seventeen. To investigate the effect of rainfall shocks on agricultural output, we also merge the UDel data with historical data on crops yields provided by 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 decline in agricultural production.

Our main results indicate that, in these areas, despite having similar effects on crop yields, droughts have *opposite* effects on early marriage: while in sub-Saharan Africa these low realizations increase the hazard of marriage before age 18, we find that in India they reduce such a hazard. Our main empirical result shows that a drought increases the annual hazard of marriage between ages 10 and 17 by 0.26 percentage points (3.9 percent) in Sub-Saharan Africa, and it decreases the hazard of marriage between ages 10 and 10 by 0.69 percentage points (7.8 percent) in India. These findings are robust to a wide set of changes to the definition of a drought, and indicate that lower rainfall is broadly associated with more child marriages in Sub-Saharan Africa and fewer in India. These effects persists for women up to age 25, and influence women's fertility as well. In particular, we find that, in Sub-Saharan Africa, a drought is associated with a 0.19 percentage points (5 percent) increase in the annual probability of having a child before turning 18.

To interpret this result, we develop an equilibrium model of child marriage in which parents can choose to time the marriage of their children in order to smooth consumption, because of the significant transfers of wealth and goods that take place at the time of marriage. In many countries in 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. During a drought, families have a higher marginal utility of consumption, and prefer to anticipate (in Sub-Saharan Africa) and delay (in India) their daughter's marriage in order to consume the transfer money. In equilibrium, though, also the grooms' families are affected by the same aggregate shocks. Hence, equilibrium marriage prices fall during droughts, and equilibrium quantities vary depending on which side of the market is more price elastic. Under virilocality, i.e. when a couple lives with the groom's family, as is common in our data, child marriages increase under bride price and decrease under dowry in equilibrium, because a man's parents value the marriage transfer less if the can rely on their son's economic support in old age, compared to a woman's parents, who are less likely to benefit from a daughter's support after she is married.

Having documented these empirical patterns in the two regions, we further examine evidence in the data that supports of our hypothesis. First, we exploit historical data on heterogeneity in marriage payments across ethnic groups collected by the anthropologist George Peter Murdock's (1967). Within sub-Saharan Africa, where there is substantial variation in local marriage payment norms, we show that the positive effect of droughts on the hazard into early marriage is concentrated in countries that have higher prevalence of ethnic groups that traditionally make bride price payments at marriage. Even within countries, the ethnic groups that traditionally engage in bride price payments are the most sensitive to droughts. Second, within India, where dowry prevails across regions, casts and religious groups, we find that strongest among hindus, who have an ancient and stronger tradition of dowry payments.

Examining the characteristics of couples that match during droughts, opposite patterns arise in the two economies. In Sub-Saharan Africa, low-educated women who end up having lower decision-making power in their household are more likely to marry during droughts, while in India, high-educated women who end up having higher say in household decision making are more likely to marry during droughts. Examining data from the Rural Economic and Demographic Survey (REDS), we find that dowries paid for marriages that occur during droughts are twenty percent lower than those paid during normal times, consistently with our model.

Finally, we further verify our findings by bringing additional evidence from Indonesia, a country within Asia, like India, but with a large number of ethnic groups traditionally practicing bride price payment and significant variation in the virilocal norm (Ashraf, Bau, Nunn, and Voena, 2016; Bau, 2016). Interestingly, the effects that we find in this country are comparable to the ones documented in Sub-Saharan Africa: household exposed to rainfall shock have a higher probability of child marriage. As predicted by our model, the effect is driven by communities that traditionally engage in bride price payments and that have a virilocal tradition.

Our paper is related to two broad strands of the economics literature. First, it fits in the broad body of research on the importance of culture and institutions in shaping economic behavior. Much of this work has looked at the role of cultural values and beliefs, such as trust, family ties, and preferences about women's role, on economic development (Fernandez, Fogli, and Olivetti, 2004; Fernandez and Fogli, 2009; Algan and Cahuc, 2010; Alesina, Algan, Cahuc, and Giuliano, 2010; Tabellini, 2010; Nunn and Wantchekon, 2011). A growing part of this literature has explored the influence of traditional social norms - behaviors that are enforced through social sanctions - on economic behavior (Bhalotra, Chakravarty and Gulesci, 2016; Platteau, 2000). For example, La Ferrara (2007) and La Ferrara and Milazzo (2012) test the implication of the matrilineal inheritance rule on inter-vivos transfer and on human capital accumulation in Ghana, where the largest ethnic group is traditionally matrilineal. In the domain of traditional marriage practices, Jacoby (1995) studies the effect of polygyny on women agricultural productivity and find that, conditional on wealth, men do have more wives when women are more productive. Tertilt (2005) shows that banning polygyny lowers fertility and shrinks the spousal age gap in sub-Saharan Africa. While marriage payments –dowry and bride price– are widespread in many regions in Africa and Asia only few studies have looked at their effect on household's economic decision. In a recent paper, Ashraf, Bau, Nunn, and Voena (2016) show that ethnic groups that traditionally engage in bride price payment at marriage in Indonesia and Zambia are more likely to see female enrollment increase in response to a large expansion in the supply of schools. In those communities, higher female education at marriage is associated with a higher bride price payment received thus providing a greater incentive for parents to invest in girls' education.

Second, our results contribute to the large economic literature that studies the coping mechanisms used by poor households to deal with income risk. Despite imperfect markets for formal insurance, credit, and assets, rural households seem well-equipped to smooth consumption in the face of short-term, idiosyncratic income shocks, often through informal insurance arrangements (see Townsend (1994), Dercon (2002), De Weerdt and Dercon (2006), Fafchamps and Gubert (2007) and Angelucci, De Giorgi, Rangel, and Rasul (2010) among others). However, in the face of aggregate shocks, households must rely on a different set of strategies to cope (Dercon, 2002). These strategies, which include migration (Morten, 2016), off-farm employment, and liquidation of buffer stock (Fafchamps, Udry, and Czukas, 1998), are typically unable to provide full consumption smoothing. This challenge is illustrated in the growing empirical literature looking at the impact of negative rainfall shocks on individual outcomes, which has identified negative effects of drought on infant and child health, schooling attainment and cognitive test score performance, increased rates of domestic violence and violence against women, and even higher rates of HIV infection (Burke, Gong, and Jones, 2014).[3] In this paper, we show that adjusting the timing of marriage is another strategy that households use to cope with aggregate variation in income, which can have harmful long-run welfare implications for young women.

The remainder of the paper proceeds as follows. Section 2 provides background information on marriage markets, marriage payments, and early marriage in India and Africa. Section 3 illustrates the equilibrium model. Section 4 describes the data used in the analysis, and Section 5 explains the empirical and identification strategy. Sections 6 and 7 summarize the results and provide robustness checks. Section 8 concludes.

2 Background

Early marriage and marriage payments are both widespread practices in developing countries, particularly in sub-Saharan Africa and in South Asia.

2.1 Early marriage

Early marriage is still a dramatic practice in many countries around the world. The practice 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; and lower literacy and educational attainment (Jensen and Thornton, 2003; Field and Ambrus, 2008). Based on these findings, international organizations such as UNICEF and the World Bank have called for “urgent action", arguing that the eradication of early marriage is a necessary step towards improving female agency and autonomy around the world.[4]

The reasons why the practice persists are numerous and inter-related. Parents often view early marriage as a socially acceptable strategy to protect their daughter against events (i.e. sexual assault, out-of-wedlock pregnancy, etc.) that could compromise her purity and subsequent marriageability (see for example Worldvision 2013; Bank 2014). 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).

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

[4]See “No time to lose: New UNICEF data show need for urgent action on female genital mutilation and child marriage", UNICEF Press Release, 22 July 2014.

Although cultural and social norms are considered important drivers of the persistence of early marriage, economic conditions also play a role. Girls from poor households are almost twice as likely to marry early as compared to girls from wealthier households (Bank, 2014). This effect is compounded by the tradition of marriage payments (dowry and bride price) in Africa and in India. In India, the prevailing tradition is for the parents of the bride to pay a dowry to the groom's family at the time of marriage, while in Africa, bride price is traditionally paid by the groom to the parents of the bride. The available empirical evidence indicates that dowry is increasing in bride's age, while bride price is at first increasing and then rapidly decreasing in bride's age, meaning that under both customs, marrying a daughter earlier can be financially more attractive for her parents.[5]

2.2 Marriage payments

The prevailing economic view of marriage payments is based on the seminal work of Becker (1991). Individuals enter into the marriage market to find the match that maximizes their expected utility; the marriage market matches partners and determines the division of surplus between them. Given this characterization, marriage payments (dowries and bride prices) may emerge as pecuniary transfers that serve to clear the marriage market. Different types of marriage payments can emerge in response to scarcity on one side of the marriage market: when grooms are relatively scarce, brides pay dowries to grooms, and when brides are relatively scarce, grooms pay bride prices to brides. Alternatively, payments can arise as the transfers to equilibrate the market when the rules for division of household output are inflexible, so that a spouse's shadow price in the marriage market differs from his or her share of household output. 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, when a woman's shadow price on the marriage market is more than her share of household output, dowries will emerge to encourage male participation on the market.[6]

[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 very limited, but for evidence on bride price and bride's age in the Kagera Health and Development Survey from Tanzania, see Corno and Voena (2016).

[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

There is an important difference between marital customs in sub-Saharan Africa and India: in Africa, 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 the sub-Saharan African sub-continent: more than than 90% of ethnic groups in sub-Saharan Africa traditionally paid bride price (Goody, 1976; Murdock, 1967). This practice is not universal in contemporary Africa, but it remains a substantial transfer across the region (see appendix table). 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 heads of cattle) was estimated to be two to four times a household's gross annual income (Decker and Hoogeveen, 2002). Relying on DHS data, Anderson (2007) 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 found to have been paid in nearly all marriages. Ashraf, Bau, Nunn, and Voena (2016) document that the practice is widespread in modern-day Lusaka (Zambia), with payments often exceeding annual per capita GDP.

The pioneering work on dowry in economics has focused on historical data from Europe (Botticini, 1999; Botticini and Siow, 2003). In contemporary India, dowry is paid in virtually all marriages (Anderson, 2007). 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. The transition from bride price to dowry began in the start of the 20th century, and has been attributed to an increasingly skewed sex ratio (more potential brides than potential grooms), which has increased competition among women for grooms, particularly educated young men with urban jobs (Caldwell, Reddy, and Caldwell, 1983). Some authors have argued that dowry payments have grown substantially over the first half of the twentieth century, a phenomenon which has been explained by slowing population growth, or as hypergamy and the caste system (Anderson, 2003; Rao, 1993; Sautmann, 2012). Edlund (2006), however, argues that actual net dowries have experienced little change. Over the period we study in our data, dowry is widespread across India and payments are large in magnitude (often significantly above

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 (2013)).

average household income).

There are numerous explanations proffered to explain the existence of dowry in India and bride price in Africa. Goody and Tambiah (1973) explain the prevalence of bride price in Africa by the continent's land abundance and low population density. 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 are distinguished by their land holdings, and women's own labor and ability to reproduce is relatively less valued. Boserup (1970) offers a slightly different hypothesis based on differences in women's agricultural productivity in the two regions. She argues that in Africa, which has a non-plough agricultural system, female labor is more important than in Asia, a region characterized by plough architecture, and this generates marriage payments to move towards the bride's side of the market. This hypothesis finds empirical support in Giuliano (2014) who documents a positive correlation between women's role in agriculture and marriage payments and has also been used to explain cross-cultural differences in beliefs on the role of women in society (Alesina, Giuliano, and Nunn, 2013).

3 Theoretical framework

In this section, we develop a simple equilibrium model where aggregate economic fluctuations affect child marriage decisions by families. Marriage payments play a crucial role and their direction determines whether more or fewer women marry early when aggregate income is low.

Below, we present a version of the model with logarithmic utility and a uniform distribution of income heterogeneity. In Appendix C, we extend this framework in two ways. First, we study how the presence of child labor, and the effect of droughts on children's wages, interacts with the marriage market and the marriage payments. Second, we extend this model to more general utility functions and distributions of the heterogeneity, showing that our propositions are valid under milder assumptions than the one presented her.

3.1 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, childhood ($t = 1$) and adulthood

$(t = 2)$.

In each period, household income depends on adult children's contributions and on an aggregate realization of weather, which can take values $y_t \in \{y^L, y^H\}$, with $y^L < y^H$, each occurring with equal probability independently in every period, plus an idiosyncratic realization ϵ_t which is distributed uniformly on $[0, 1]$. Hence, in period t, the total income of a household i with an adult daughter is equal to $y_t + \epsilon_t^i + w^f$, where w^f is a woman's contribution to the household budget. Following Boserup's (1970) interpretation of the historical origins of marriage payments, we consider *historical* w^f to be either positive or negative depending on the available technology in the local community: $w^f > 0$ then generate bride price payment, while a dowry system emerges when $w^f < 0$. The total income of a household j with an adult son is equal to $y_t + \epsilon_t^j + w^m$. The discount factor is denoted by δ.

The society is patrilocal, and hence upon marriage women move to the groom's family and contribute to its budget. In addition, with marriage, the groom's family acquires offspring, which deliver utility $\xi^m > 0$. There is also a potential utility gain of a woman's family stemming from marrying off a daughter (i.e. stigma associated with non-married women), denoted as $\xi^f \geq 0$.

3.2 Adulthood

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). In adulthood, marriage occurs if both parties prefer it to remaining single. A transfer may be needed to achieve such an outcome: this implies that there exists a τ_2^* that satisfies

$$ln(y_2 + \epsilon_2^i + \tau_2^*) + \xi^f \geq ln(y_2 + \epsilon_2^i + w^f)$$

$$ln(y_2 + \epsilon_2^j + w^m + w^f - \tau_2^*) + \xi^m \geq ln(y_2 + \epsilon_2^j + w^m).$$

When income is sufficiently low, the bounds on τ_2^* require a payment to take place even for the richest families. In sub-Saharan Africa, with historical $w^f > 0$, a bride price payment is necessary to persuade women's parents to let their daughters marry, meaning that

$$ln(y_H + 1 + w^f) > ln(y_H + 1) + \xi^f.$$

In India, where historically $w_f < 0$, a dowry payment is necessary to persuade men to support a bride into their household:

$$ln(y_H + 1 + w^m) > ln(y_H + 1 + w^m + w^f) + \xi^m.$$

These conditions imply that a lower bound on the marriage payment is equal to $\underline{\tau}_2 = \frac{1-exp(\xi^f)}{exp(\xi^f)}(y_2 + \epsilon_2^i) + \frac{w^f}{exp(\xi^f)}$, while the upper bound is $\bar{\tau}_2 = \frac{exp(\xi^m)-1}{exp(\xi^m)}(y_2 + \epsilon_2^j + w^m) + w^f$. In what follows, we assume that there exists a payment $\tau_2^* \in [\underline{\tau}_2, \bar{\tau}_2]$. One simple example of equilibrium is that men make a take-it-or-leave-it offer to the woman's parents, and the parents decide whether or not to accept. For example, when $\xi^f = 0$, men offer $\tau_2^* = w^f$. Hence, whenever $w^f < 0$, the transfer is a dowry, i.e. a payment from the bride's family to the groom's family, while with $w^f \geq 0$, the payment is a bride price, i.e., a payment from the groom's family to the bride's family.

Following Boserup's interpretation, the direction of the marriage payment may be due to the historical sign of w^f, but in what follows, we do not impose that present-day w_f has to differ across areas of the world. In this sense, the fact that marriage payments are the way by which the marriage markets clear and whether in adulthood grooms' families ($\tau_2 > 0$) or brides's families ($\tau_2 < 0$) make such payments are cultural norms in this model, intended as a way of selecting among multiple equilibria (Greif, 1994).

Given the payment τ_2^*, payoffs from marrying in the second period are:

$$ln(y_2 + \epsilon_2^j + w^m + w^f - \tau_2^*) + \xi^m \qquad \text{and} \qquad ln(y_2 + \epsilon_2^j + \tau_2^*) + \xi^f.$$

If a couple is already married when entering the second period, the families' payoffs instead are

$$ln(y_2 + \epsilon_2^j + w^m + w^f) + \xi^m \qquad \text{and} \qquad ln(y_2 + \epsilon_2^i).$$

3.3 Childhood

In the first period, parents decide whether or not to have their children marry. For a given transfer τ_1 paid in marriages that occur in the first period, payoffs are the following.

If marriage occurs:

$$ln(y_1 + \epsilon_1^j - \tau_1) + \delta E\left[ln(y_2 + \epsilon_2^j + w^m + w^f) + \xi^m\right]$$

$$ln(y_1 + \epsilon_1^i + \tau_1) + \delta E\left[ln(y_2 + \epsilon_2^i) + \xi^f\right].$$

Instead, if marriage is delayed:

$$ln(y_1 + \epsilon_1^j) + \delta E\left[ln(y_2 + \epsilon_2^j + w^f - \tau_2^* + w^m) + \xi^m\right]$$

$$ln(y_1 + \epsilon_1^i) + \delta E\left[ln(y_2 + \epsilon_2^i + \tau_2^*) + \xi^f\right].$$

A woman from household i will get married in the first period if and only if:

$$ln(y_1 + \epsilon_1^i + \tau_1) - ln(y_1 + \epsilon_1^i) \geq \delta E\left[ln(y_2 + \epsilon_2^i + \tau_2^*)\right] - \delta E\left[ln(y_2 + \epsilon_2^i)\right]$$

A man from household j will get married in the first period if and only if:

$$\begin{aligned} ln(y_1 + \epsilon_1^j - \tau_1) - & ln(y_1 + \epsilon_1^j) \geq \\ & \delta E\left[ln(y_2 + \epsilon_2^j + w^m + w^f - \tau_2^*)\right] - \delta E\left[ln(y_2 + \epsilon_2^j + w^m + w^f)\right]. \end{aligned}$$

Define the right handside terms as $\Omega^f = \delta E\left[ln(y_2 + \epsilon_2^i + \tau_2^*) - ln(y_2 + \epsilon_2^i)\right]$ and $\Omega^m = \delta E\left[ln(y_2 + \epsilon_2^j + w^m + w^f - \tau_2^*) - ln(y_2 + \epsilon_2^j + w^m + w^f)\right]$. For simplicity, define also $H^f = exp(\Omega^f)$ and $H^m = exp(\Omega^m)$.

3.3.1 Demand and supply for brides in sub-Saharan Africa

When $\tau_2^* > 0$, $\Omega^f > 0$ and $H^f > 1$. Also $\Omega^m < 0$ and hence $H^m < 1$.

For a given τ_1, define a marginal household with daughter i such that:

$$ln(y_1 + \epsilon_1^{f*} + \tau_1) - ln(y_1 + \epsilon_1^{f*}) = \Omega^f$$

Given the expression above, there exists a threshold income shock for women's parents such that, when $\epsilon_t^i < \epsilon^{f*}(\tau_1)$, parents will want their daughter to marry in the first period. Hence, because of the uniform assumption, a measure ϵ^{f*} of women wants to get married. The supply of brides, defined on the $[0, 1]$ interval, takes the form

$$S^{SSA}(y_1, \tau_1) = \frac{\tau_1}{H^f - 1} - y_1.$$

and is decreasing in the aggregate income y_1 and increasing in τ_1.

For a given τ_1, also define a marginal household with son j such that:

$$ln(y_1 + \epsilon^{m*} - \tau_1) - ln(y_1 + \epsilon^{m*}) = \Omega^m.$$

For $\epsilon_t^j > \epsilon^{m*}$, men want to also marry in the first period. Hence, because of the uniform assumption, a measure $1 - \epsilon^{m*}$ wants to get married. The demand for brides, again defined on the $[0, 1]$ interval, takes the form

$$D^{SSA}(y_1, \tau_1) = 1 + y_1 + \frac{\tau_1}{H^m - 1},$$

which is increasing in the aggregate income y_1 and decreasing in τ_1.

3.3.2 Demand and supply for brides in India

In India, $\tau_2^* < 0$. This implies that $\Omega^f < 0$ and hence that $H^f < 1$. Also $\Omega^m > 0$ and hence $H^m > 1$.

The supply of brides takes the form

$$S^{IND}(y_1, \tau_1) = 1 + y_1 - \frac{\tau_1}{H^f - 1}$$

and is increasing in the aggregate income y_1 and increasing in τ_1 (which is the opposite of the dowry). The demand for brides takes the form

$$D^{IND}(y_1, \tau_1) = -y_1 - \frac{\tau_1}{H^m - 1}$$

which is decreasing in the aggregate income y_1 and decreasing in τ_1.

3.3.3 Equilibrium in the marriage market

Equilibrium marriage payment which clears the marriage market in the first period is the one that solves $D(y_1, \tau_1^*) = S(y_1, \tau_1^*)$, which in both economies leads to

$$\tau_1^*(y_1) = \frac{(H^f - 1)(H^m - 1)}{H^m - H^f}(1 + 2y_1).$$

Equilibrium quantities are computed by substituting the equilibrium price in the demand or in the supply equation. Equilibrium quantities of marriages is equal to

$$Q(y_1)^{SSA} = \frac{1 + 2y_1 - H^f y_1 - H^m(1 + y_1)}{H^f - H^m}, \qquad Q(y_1)^{IND} = \frac{1 + 2y_1 - H^f(1 + y_1) - H^m y_1}{H^m - H^f}.$$

Proposition 1. *For sufficiently large w^m, aggregate income decreases the number of child marriage in equilibrium in societies in which marriage payments are positive (i.e. bride price), and increases the number of child marriage in equilibrium in societies in which marriage payments are negative (i.e. dowry).*

Proof. See Appendix C. □

Intuitively, our results carry through when the supply curve for brides is flatter (slope $\frac{1}{H^f-1}$ in SSA and $-\frac{1}{H^f-1}$ in India) than the demand curve for brides (slope $-\frac{1}{H^m-1}$ in SSA and $\frac{1}{H^m-1}$ in India, see Figure 1). This happens because a son's income provides insurance to his parents, thus reducing the absolute value of the option of waiting to marry in the second period and making the change in the equilibrium quantity of marriage when aggregate income changes more reflective of the bride's family's response than of the groom's family's response .

In other words, both the demand and the supply of brides are affected by the aggregate income. The key to why equilibrium quantities are different in different economies is that women's families are less price sensitive then men's families, who can rely on the son's income even after the marriage has occurred.

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

Proposition 2. *Marriage payments are lower when aggregate income is lower.*

Proof. See Appendix C. □

This finding, particularly in the case of Sub-Saharan Africa, is in line with the literature on firesales, in which assets are liquidated at lower prices during recessions (Shleifer and Vishny, 1992). Here, droughts are associated with low aggregate output, which is associated with lower prices irrespectively of the direction of the payments.

4 Data and descriptive statistics

We next describe the different sources of data we exploit to test the predictions of our model. All datasets used in the analysis are summarized in Appendix table A1.

4.1 Marriage data

Our first key variable is a woman's age at first marriage. To calculate that we use data from the Demographic and Health Surveys (DHS) for sub-Saharan Africa and from the DHS and India Human Development Survey (IHDS) for India.[7] For sub-Saharan Africa, we assembled all DHS surveys between 1994 and 2013 where geocoded data are available, resulting in a total of 72 surveys across 30 countries. In these surveys, GPS data consist of the geographical coordinates of each DHS cluster (group of villages or urban neighborhoods) in the sample. The list of African countries and survey waves included in the analysis is reported in the Appendix table A2.

For India, we use the DHS survey from 1998 and the IHDS survey from 2004-05. 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 the data to weather outcomes.[8]

Across all the surveys, the information on woman's age at first marriage is collected retrospectively during the woman's interview: women are asked to recall the age, month and year when they were first married.[9] The main difference across the surveys is the universe of women that is sampled for the female interview. In the DHS surveys from Africa, all women in the

[7]DHS surveys are nationally-representative, household-level surveys carried out in developing countries around the world. The DHS program is funded by USAID, and has been in existence since the mid-1980s. The India Human Development survey 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.

[8]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 dat with the IHDS instead.

[9]The India DHS does not ask the month of first marriage.

household between the ages of 15 and 49 are interviewed. In contrast, in the DHS surveys from India, all *ever-married* women aged 15-49 in the household are interviewed; and in the IHDS, only *one ever-married* woman aged 15-49 is interviewed in each household. In order to ensure comparability across surveys and avoid bias resulting from the omission of never-married women in the sample from India, we limit our analysis to women who are at least 25 years old at the time of the interview. By this point, most women are married (87% in our African sample), contributing to the comparability of the two samples. To look at comparable cohorts across the two sets of surveys, we focus on women born between 1950 and 1989. Furthermore, in the light of the evidence on rainfall and intensity of civil conflict (Miguel, Satyanath, and Sergenti, 2004), we exclude women exposed to major civil conflicts. To do so, we use data from UCDP/PRIO Armed Conflict Dataset on the onset and end of main conflicts in Sub-Saharan Africa in our sample period, as detailed in Appendix table A3.

As reported in table 1 Panel A, our final sample consists of about 340,000 women in sub-Saharan Africa, and 97,000 women in India. Figure 2 plots the distribution of ages of marriage in our data. We consider women who marry from age 10 onward. In both regions, the hazard into early marriage is relatively low up until age 13 or 14, which is consistent with the finding that girls are often considered to be ready to marry 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, 16.5 years in India and 17.4 years in Africa, and a significant fraction of women are marrying before age 18 (66.4% and 56.3% in India and Africa, respectively).

4.2 Weather data and construction of weather shocks

To test how income shocks affect the early marriage hazard for young women, we follow an approach that is widely used in the literature, exploiting variation in local rainfall as a proxy for local economic conditions. The appeal of this approach is that rainfall is an exogenous event that has meaningful effects on economic productivity in rural parts of Africa and India, where most households rely heavily on rain-fed agriculture for their economic livelihood (Jayachandran, 2006; Schlenker and Lobell, 2010; Burke, Gong, and Jones, 2014; Shah and Steinberg, 2016). Negative rainfall shocks (i.e. droughts), in particular, tend to suppress agricultural output, which has deleterious effects on households' incomes.

We use rainfall data produced by geographers at the University of Delaware ("UDel data") to construct rainfall shock measures that capture anomalously high and low rainfall realizations relative to what is typically experienced in a particular location. 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.[10] 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 2,767 unique grid cells across the sub-Saharan African region, each of which is approximately 2,500 square kilometers 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, 502 are represented in our main sample, and these districts have a mean area of 5,352 square kilometers.

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 (2014) 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 (1960-2010) of rainfall observations to fit a gamma distribution of calendar year rainfall for each location (grid cell or district). 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.

By constructing rainfall shocks in this manner, we address two important requirements needed for the validity of our study. First, our rainfall shock measures must have a meaningful economic impact on household incomes. Second, the shock measures must be orthogonal to other factors that also affect marriage decisions, such as the general level of poverty in an area, access to schooling and, more general, economic opportunities for young women. The first condition is essential to ensuring that rainfall shocks are an appropriate proxy for local economic conditions, while the second condition limits concerns about a spurious relationship between weather shocks and the early marriage hazard. To provide further confidence that we have satisfied the first condition, we next investigate the relationship between our constructed

[10] 0.5 degrees is equivalent to about 50 kilometers 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 (2014)). For a detailed overview of the UDel data and other global weather data sets, see Dell, Jones, and Olken (2013).

rainfall shock measures and agricultural yields in Africa and India.

By examining realizations that have the same probability that occur in any cell or district (a percentile of the local rainfall distribution), we limit concerns regarding the correlation between rainfall shocks and unobserved local characteristics. In figure B1 we plot the percentage of grid cells (for SSA) 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 experience a shocks in each region is around 15%. Most importantly, figure B1 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.

4.3 Weather shocks and crop yields

While the relationship between weather shocks and agricultural output is well established in the literature (see for example, Jayachandran (2006); Schlenker and Lobell (2010); Shah and Steinberg (2016); Burke, Gong, and Jones (2014)), in this section we explore how our constructed measure of rainfall shocks affects aggregate crop yields in 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 India over the 1957-1987 period from the World Bank India Agriculture and Climate Data Set.

For Africa, we estimate the impact of rainfall shocks on yields of the main staple crops growing in the continent: maize, sorghum, millet, rice, and wheat. We also estimate the impact of shocks on yields for all the natural logarithm of the cereals available in our dataset (which includes maize, rice, wheat, sorghum, millet plus barley, rye, oats, buckwheat, fonio, triticale and canary seeds). Since we have country-level yield data, we construct measures of country-level droughts in the same manner used in the main analysis.

As shown in table 2, droughts (rainfall below the 15th percentile) reduce maize, rice, wheat, sorghum and millet yield both throughout the set of sub-Saharan African countries available in the FAO database (columns 1-6) and also by focusing on the 30 countries part of our sample (columns 7-12). In particular, droughts reduce average cereals yields by 12 percent.

Similarly, for India, we rely on district-level yield data from the World Bank, which has the great advantage of providing crop yields by district. We look at the impact of rainfall shocks (constructed at the district-level) on the natural logarithm of the yields of the five most important crops in the country (rice, wheat, jowar, maize and bajra), as well as on all the staple crops in the districts in our sample (rice, maize, wheat, bajra, sesamum, ragi, jowar, sunflower). As reported in 3, droughts negatively affects yields of all crops, and reduce average yields by 16% overall.

These finding are supported by the results in A1 and A2, where we plot the coefficients for dummies for each vingtile of the rainfall realization on the natural logarithm of crop yields, to explore the relationship between rain and yields across the distribution of rainfall realizations. While low rainfall is clearly associated with low output, it is harder to identify a clear positive relationship between high rainfall and output, at least in the coarse units of observation. In particular, high rainfall appears to positively associated with output for rice, especially in India. We conclude that our drought measure serves as a strong proxy for a negative output shock in both regions, while floods are an inconsistent proxy for income, as their effect varies dramatically depending on the underlying crop.

5 Empirical strategy

To examine the impact of weather shocks on the incidence of early marriage, we estimate a simple duration model, adapted from Currie and Neidell (2005). Below we discuss our baseline specification and potential threats to identification.

5.1 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 10, 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. A woman who is married at age t_m is treated as if she contributed ($t_m - t_0 + 1$) observations to the sample: one observation for each at-risk year until she is married, after which she exits the data. We merge this individual-level data to the marriage data according to the year of the rainy season most likely to precede the potential marriage season. In Sub-Saharan Africa, where there is typically one rainy season in the fist 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 season is in the second half of the year, we consider rainfall in the year preceding the one in which the woman is age t.

Table 1 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 Africa, district in India) born in cohort k and entering her first marriage at age t as follows:

$$M_{i,g,k,t} = \beta' X_{g,k,t} + \alpha_t + \omega_g + \gamma_k + \epsilon_{i,g,k,t}. \tag{1}$$

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 early marriage, in most regressions we only include data on women through age 17. Thus, women married after age 17 are right censored.[11] In this equation, $X_{g,k,t}$ are time-varying measures of weather conditions in location g during the year in which the woman born in year k is age t. Specifically, included in $X_{g,k,t}$ are a dummy indicator for a drought in a given year, and a dummy indicator for a flood in that year. β are the main coefficients of interest and measure the effect of rainfall shocks on the probability of marriage. α_t is age fixed effect, a measure of duration dependence 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 unobservables at the location level such as geographic, economic and cultural factors that do not vary over time, and year-of-birth fixed effects γ_k to account for cohort effects.[12] Each time-invariant covariate is repeated for every period, and time-varying covariates (the weather shocks) are updated each period. Since we are combining data across multiple survey instruments, we use population-weighted survey weights to make results representative of the countries included in the analysis. We estimate regressions with standard errors clustered at the grid-cell (for Africa) or district (for India) level, to allow for serial correlation in error terms across individuals in the same area.

[11] For example, a woman who is married at age 16 would appear seven times in the data, and her marriage vector would be $\{M_{i,k,10}, ..., M_{i,k,15}, M_{i,k,16}\} = \{0, ..., 0, 1\}$. A woman who is not married by age 17 appears in the data eight times, and her marriage vector is a string of zeroes.

[12] As discussed in Section 4, there are 502 districts represented in our main sample for India, with an average geographic area of 5,352 square kilometers and an average of 125 women per district. There are 2,767 grid cells represented in our main sample for Africa, with an average geographic area of 2,500 square kilometers and an average of 84 women per grid cell.

With the inclusion of location (grid cell or district) and year of birth fixed effects, the impact of weather shocks on the early 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. Each area is equally likely to have experienced a shock in any given year, so identifying variation comes from the random timing of the shocks. 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 for. 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 marital timing decisions (Vogl, 2013).

5.2 Threats to identification

A potential threat to identification comes from the fact that we are considering weather shocks in the place of residence at the time of the survey. Indeed, in all our sources of data, we only have information on where women currently reside, and not on where they resided around the time she was first married. This introduces two potential problems to the analysis. The first one relates to the custom of patrilocal exogamy. 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, women move away from their natal village at the time of marriage, so that the village they live in at the time of the interview is different than the village where they grew up. The second concern is that women and their families may migrate at a later point, after marriage but before the survey takes place.

The seminal paper on marriage migration (Rosenzweig and Stark, 1989) argues that this phenomenon is adopted to informally insure families against shocks: 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 the possibility of making inter-household transfers in times of need.While patrilocality 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 4 shows migration pattern for the set of African countries in our analysis and for India. Panel A, column 1, shows that more than 40% of women report never moving from their natal home. Furthermore, when migration does occur, previous literature suggests that happens across relatively short distances. Mbaye and Wagner (2013) collect data in Senegal and find that women live an average of 20 kilometers from their natal home, which is inside the geographic boundaries of 2,500 squared kilometers at Equator we used to define weather shocks. [13]

In India, 58.02% of women migrated at the time of marriage, but again migration happens at close distances or within geographic area at which we define our rainfall shocks. In the IHDS, the average travel time between a married woman's current residence and her natal home is about 3 hours and 6 hours for the 90% of the respondents (see table 4, panel B). To better understand migration pattern in India, we also look at findings from previous literature. In Rosenzweig and Stark's South Indian village data (ICRISAT), the average distance between a woman's current place of residence and her natal home is 30 kilometers. As described in Atkin (2016), according to the 1983 and the 1987-88 Indian National Sample Surveys (NSS), only 6.1 percent of households are classified as "migrant households", those for which the enumeration village differs from the respondent's last usual residence. Furthermore, only a small percentage of women move after marriage and even if they migrate, they do not move very far away.

To study this issues more closely, we estimate the correlation between the occurrence of a drought at the time of marriage for child brides and a set of marriage migrations outcomes from the DHS and the IHDS. In Sub-Saharan Africa, women do nor appear less likely to have remained in their village of birth (table 5, column 1). However, they are less likely to have migrated at during a drought, a mechanism that should bias our estimates downward (column 2). In India, we do not find that drought affect marriage migration, nor distance from the village of origin (table 5, columns 3-5).

Taken together, the available information on marriage migration in Africa and India suggests that most of the women who move from their natal home at the time of marriage are not likely to be migrating out of the geographic areas for which we define our weather shocks.

Another potential threat to identification 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, validations studies of age variables in the DHS have suggested that such measures are rather accurate (Pullum, 2006), limiting concerns about measurement error.

[13]Unfortunately, information on the distance from natal home to the current location is not included in the DHS data.

6 Main results

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

6.1 Effect of rainfall shocks on child marriage

Table 6 displays results of estimating equation 2 on the data from Sub-Saharan Africa (columns 1-3) and India (column 4-7). All specifications for the African sample include grid cell fixed effects and those for India include district fixed effects. Results show that a drought has opposite effects on the early marriage hazard in the two regions: in Africa, droughts increase the hazard into early marriage; in India, drought decreases the hazard. In term of magnitude, droughts increase the early marriage hazard by 0.27 percentage points and in SSA (Column 1), and the finding is robust to controlling for country fixed effects and the interaction between country and cohort of birth fixed effects, which controls for cohort-specific changes in marriage behavior at the country level, such a change in the legal age at marriage.[14] In India, a drought decreases the early marriage hazard by 0.38 percentage points in the 1998 DHS (column 4) and by 0.69 percentage points in the combined DHS and IHDS data (Column 6).

6.2 Robustness of the main findings

As a first robustness check, we investigate 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 for varying cutoff levels to determine drought, ranging from the 5th percentile to the 45th percentile. Figure 5 plots the estimated coefficients for different cutoff percentiles for drought, along with 95% confidence intervals. In both regions, the point estimate is fairly stable around the default 15th percentile cutoff, and as definition of drought becomes more severe, the estimated impact increases in absolute value.

Second, we estimate our main regression equation with indicators for the bottom rainfall quintiles between 1960 and 2010. Effects are comparable to our measure of drought (see table 7).

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

Third, we examine the association between the level of rain 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 0.75 percentage points in SSA (table 8, column 2), and with an increase in such a hazard by 0.56 percentage points in India (column 6), although the effect of rain is only significant in the combined DHS and IHDS sample.

To further examine the relationship between rainfall shocks and child marriage, we define floods as rainfall realizations that exceed the 85th percentile of rain. When we include floods to our main specification, we find that floods reduce the child marriage hazard both in Sub-Saharan Africa and in the DHS sample India (table 9, columns 1-4), but not in the IHDS (columns 5 and 6). In Sub-Saharan Africa, however, floods are associated with increases in crop yields (A1), while in India, the negative effect of floods is concentrated in regions that do not cultivate rice and hence are more likely to experience an decrease in yields during floods (A2).

As an additional robustness check, we verify that our findings that our findings persist when we do not use weights (table 10 columns 1 and 3) and when we use the most recent wave of data for each country (columns 2 and 4). Hence, this test implies that we can verify that our findings from India hold in the IHDS independently: we find that in such a sample, a drought is associated with a 0.97 percentage points decline in the child marriage hazard.

6.3 By age

The results presented so far estimate the average effect of weather shocks across all ages represented in the data (age 10 to age 17). However, the baseline hazard into marriage varies significantly within this age range, suggesting that the effects of income shocks may also vary. To investigate this possibility, we estimate a version of Equation (1) that interacts weather shocks with indicators for each age dummy between age 10 and age 17.

Figure 4 panel a reports the results of the analysis. We see that the effects of drought are concentrated around age 16 in both countries. We also extend the age range up to age 25 (figure 4 panel b and c). We show that the effect of rainfall persists well past child marriage, particularly in Sub-Saharan Africa.

6.4 Effects on early fertility

In table 11, we examine how droughts affect the onset of fertility, by replacing the marriage outcome variable with a variable that takes value 1 in year of birth of the first child. As expected when marriage occurs early, we find that droughts also lead women to have children earlier in Sub-Saharan Africa, with a 0.019 percentage points increase in the annual hazard of having the first child below age 18, corresponding to a 4.3% increase. We find no effects of rainfall shocks on the timing of fertility in India.

These findings are particularly important to emphasize that, at least in Sub-Saharan Africa, droughts do not simply affect the onset of formal marriage, but have real effects on women's lives.

7 Mechanism: evidence on the direction of marriage payments

In this section, we present a set of empirical findings to examine the mechanism that may generate the heterogeneity that we have uncovered. Our hypothesis, as illustrated in our theoretical model, is that the direction of traditional marriage payments generates in incentive for parents to time their children's marriage as a consumption smoothing mechanism.

7.1 Prevalence of bride price in sub-Saharan Africa

To test whether traditional marriage payments do play a role in explaining the differential effect of rainfall shocks on early marriages, we exploit heterogeneity in marriage payments across ethnic groups in different countries within Sub-Saharan Africa. Our data source for measures of traditional marriage customs in different ethnic groups is George Peter Murdock's (1967) *Ethnographic Atlas.* The Atlas provides information on transfers made at marriage, either bride price or dowry, by ethnic groups.

In table 12, we report the estimated effects of rainfall shocks in sub-Saharan African countries with a share of individuals historically belonging to ethnic groups with bride price prevailing norms higher than 50% and 80%, based on *Ethnomaps* (see A4), which combines the *Ethnographic Atlas* with population data at the ethnic group level. Countries with a bride price prevalence equal or greater than 50% include all SSA countries except Madagascar, Malawi, Mozambique and Zambia. Countries with a bride price prevalence equal or greater than 80% include all SSA countries except Madagascar, Malawi, Mozambique, Zambia, CAR, Ivory Coast, Ethiopia, Gabon, Namibia and Togo. Table 12 shows that the effect of drought on the early marriage hazard is concentrated in countries that have a high prevalence of bride price payment.

In Appendix table A6 , we test the effect of rainfall shocks on early marriage in Zambia, a country in SSA where there is substantial heterogeneity by ethnic groups in bride price payment. Following Ashraf, Bau, Nunn, and Voena (2016), we merge the ethnic group of the respondent in the Zambia DHS with the Murdock's (1967) *Ethnographic Atlas*. We show that, even within the same country, the effect of rainfall shock is concentrated among groups that traditionally engage in bride price payments. Estimates on the effects of droughts lack precision in this smaller sample.

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

To examine the characteristics of marriages that form during years of drought and flood, we examine the following specifications, for household i living in location g (grid cell in Africa, district in India) born in cohort k and married in year τ:

$$y_{i,g,k,\tau} = \beta' X_{g,k,\tau} + \delta_\tau + \omega_g + \gamma_k + \zeta_i + \epsilon_{i,g,k,\tau}. \tag{2}$$

In this specification, $X_{g,k,\tau}$ are time-varying measures of weather conditions in location g during the year in which the woman marries τ. We control 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 estimated, as they are the result of both selection forces (i.e. the characteristics of people who chose to marry during a drought may differ) and causal forces (i.e. the fact that a couple married during a drought leads to different long-term outcomes).

In Sub-Saharan Africa, we find that the women who marry during droughts are more likely to be uneducated (column 1), and they tend to marry men of similar education and age as those who marry during regular times (column 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 have less say in household decision making compared do their husband (column 6).

In the data from India, we tend to find the opposite patterns. Women who marry during droughts are less likely to be uneducated (column 1), and they tend to marry men of similar education and age as those who marry during regular times (column 2-3). While estimates of decision making are imprecise, as the question differ between IHDS and DHS, the point estimates in both DHS and IHDS suggest that women who marry during droughts have more say in household decision making compared to their husband (columns 4 and 5).

7.3 Magnitude of dowry payments

An implication of our model is that matches that form during droughts should command lower payments. To study this implication, 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 respondents' daughters. Following Roy (2015), we define as dowry paid the gross amounts paid, and we express it real terms (2010 Indian Rupees). In this sample, the mean payment is equal to 77,306 INR, with a standard deviation of 195,034. As shown in table 16, there is a negative association between dowry paid and marriages occurred during droughts, which are around 20% lower than baseline. This finding is consistent with proposition 2, but may also be due to a differential selection of women into marriage. While controlling for spouses' age of marriage (columns 2 and 6), spouses' education (columns 3 and 7) and parents' education (columns 4 and 8) does not substantially change our estimates, we lack other information about the bride's and the groom's characteristics.

8 Additional evidence from Indonesia

To examine the validity of our interpretation in a new context, we move the analysis to Indonesia, an Southeast-Asian country with an ancient bride price tradition among 46% of all its ethnic groups (Murdock, 1967), as documented extensively in Ashraf, Bau, Nunn, and Voena (2016). Bau (2016) studies heterogeneity across virilocal and uxorilocal groups, which is another important source of potential heterogeneity in this sample. Rich data from the Indonesia Family

Life Survey (IFLS) allows us to test the mechanisms underlying our effects.

8.1 Data

We use data from the 3rd and 4th rounds of the IFLS, with information about marriage and migration history. Figure 6 reports the distribution of ages at marriage for women aged 25 and above at the time of the interview. In this sample, 31% of women marry before age 18.

We merge the UDel data aggregated at the level of province to the 21 provinces of birth of 7,857 female respondents in the IFLS, and expand the dataset to maintain the same specification discussed above for SSA and India. One particular advantage of the IFLS is that it records a woman's migration history, allowing us to concentrate on the province of birth of each respondent, rather than the province of residence.

8.2 Empirical analysis

By replicating our analysis in this new context, we find that a drought is associated with a 0.5 percentage points increase in the annual hazard of child marriage (table 18, columns 1 and 2), with a baseline hazard of 4.2. Following Ashraf, Bau, Nunn, and Voena (2016), we combine our merged data to Murdock's *Ethnographic Atlas* to identify respondents who belong to ethnic groups that traditionally engage in bride price payments and who are virilocal (a variation that is non-existent for groups that do not engage in bride price payments). We show that effects are concentrated among virilocal groups that make bride price payments (table 18, columns 3 and 4).

9 Concluding remarks

This paper presents empirical results showing that negative weather shocks, which proxy for aggregate negative income shocks, have opposite effects on the probability of child marriage in sub-Saharan Africa and India. In Africa, drought leads to an increase in the early marriage hazard, while in India, drought leads to a decrease in the early marriage hazard. These findings are informative for policy aimed at reducing the prevalence of child marriage in the developing world for two reasons. First, they provide evidence that marital timing decisions are indeed shaped by economic conditions. Second, they underscore the important interdependencies between prevailing cultural institutions and household responses to economic hardship, which suggests that policies may need to account for local customs and practices to be effective.

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Figures and Tables

Figure 1: Equilibrium outcomes

(a) Sub-Saharan Africa (b) India

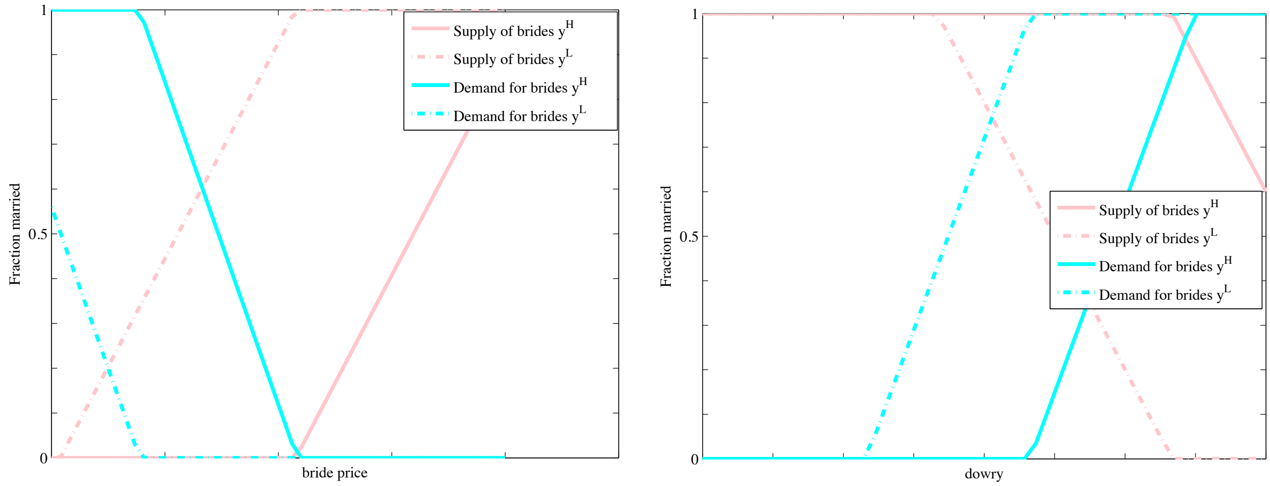
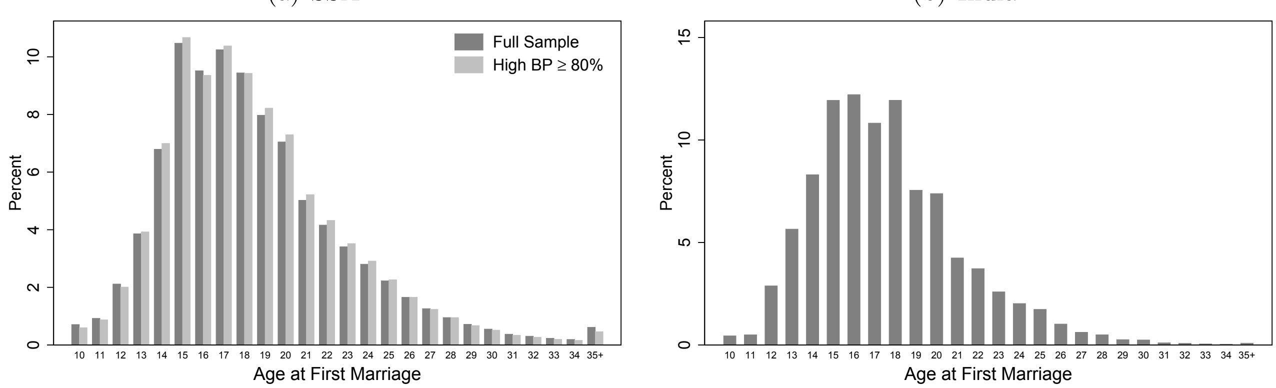


Figure 2: Distribution of the Ages at First Marriage

(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 3: Marriage payments in the sample

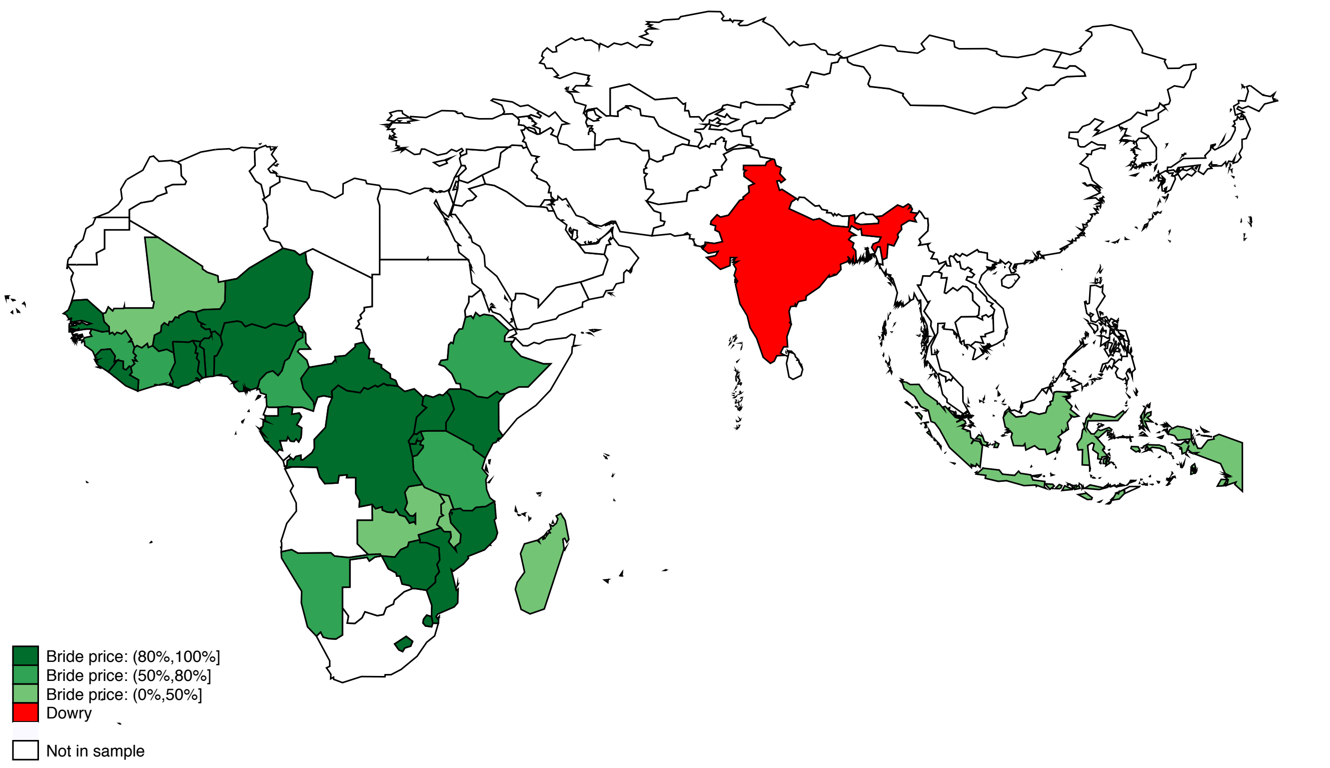
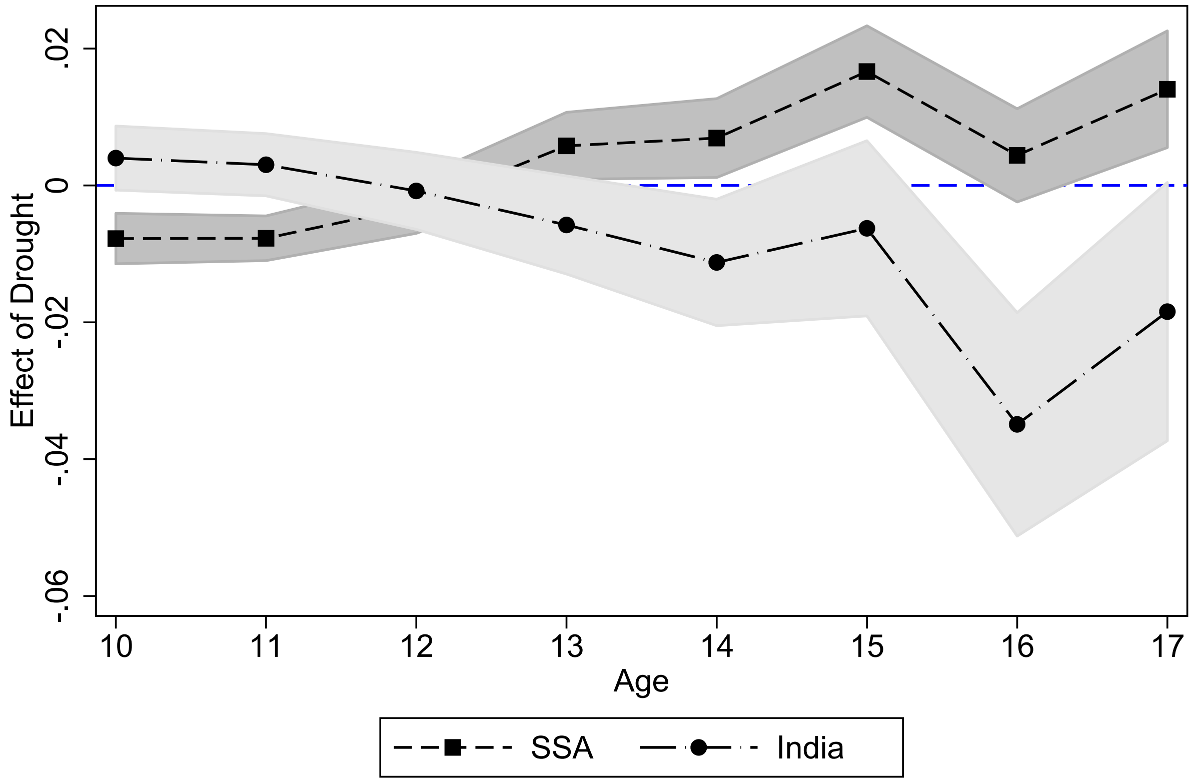
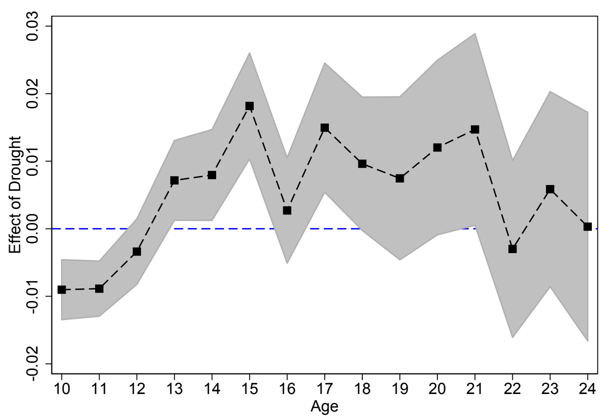


Figure 4: Effect of Drought on Marriage by Age

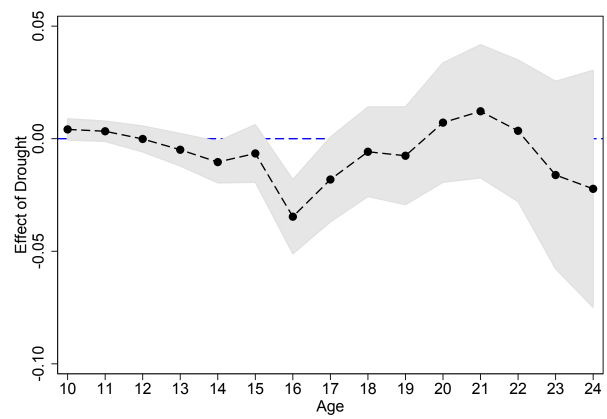
(a) Combined



(b) SSA BP $\geq$ 80%

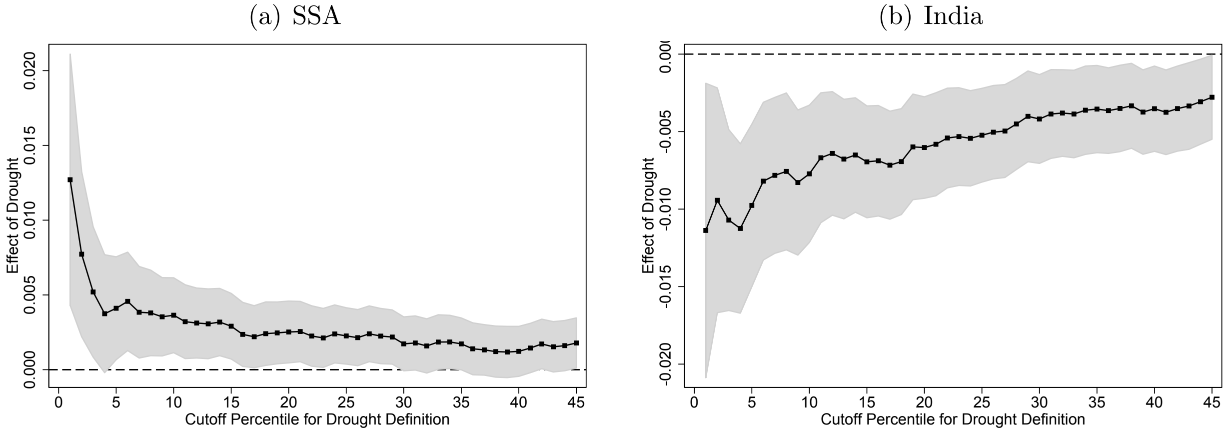


(c) India



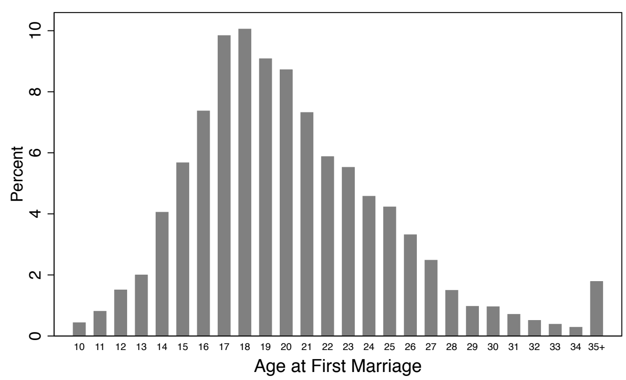
Note: Figure shows the effect of drought by age estimated using the high bride price (BP) Sub-Saharan Africa (SSA) and full India regression samples. The lines show the estimated coefficients and the gray bands show the 95% confidence intervals calculated using standard errors clustered at the grid cell (SSA) or district (India) level.

Figure 5: Robustness in the Definition of Drought Based on Cutoffs in Rainfall Distribution



Note: Figures show the point estimates of the effect of drought on early marriages, estimated using OLS regressions for the high bride price (BP) Sub-Saharan Africa (SSA) and full India 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 gray bands 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$^{\text{th}}$ percentile of the long-run rainfall distribution.

Figure 6: Distribution of the Ages at First Marriage in Indonesia



Note: Figures show the distribution of ages at first marriage for individuals in our IFLS 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.

Table 1: Summary Statistics for Regression Samples: Sub-Saharan Africa and India

	SSA			India		
	Obs.	Mean	Std. Dev.	Obs.	Mean	Std. Dev.
Panel A: Full Sample						
Unique Individuals in Sample	343,483			96,954		
Percent Married Between Ages 10-17	2,447,982	6.58	24.80	674,819	8.86	28.41
Percent Drought	2,447,982	16.53	37.14	674,819	15.45	36.14
Birth Year	2,447,982	1,971.59	8.24	674,819	1,967.38	7.31
Age	2,447,982	13.19	2.22	674,819	13.08	2.18
Panel B: High BP ($\geq$ 80%) Countries						
Unique Individuals in Sample	243,737					
Percent Married Between Ages 10-17	1,721,283	6.69	24.98			
Percent Drought	1,721,283	16.52	37.14			
Birth Year	1,721,283	1,971.64	8.02			
Age	1,721,283	13.18	2.22			

Note: Table shows summary statistics for the main Sub-Saharan Africa (SSA) and India regression samples: women aged 25 or older at the time of interview. Observations are at the level of person $\times$ age (from 10 to 17 or age of first marriage, whichever is earlier). Statistics are weighted to be representative of the included countries (SSA) or districts (India).

Table 2: Weather Shocks and Crop Yields in Sub-Saharan Africa

	All SSA						DHS SSA Only					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Maize	Sorghum	Millet	Rice	Wheat	Average	Maize	Sorghum	Millet	Rice	Wheat	Average
Drought	-0.11***	-0.13***	-0.080**	-0.11***	-0.059*	-0.12***	-0.12***	-0.11***	-0.083**	-0.12***	-0.067	-0.12***
	(0.028)	(0.035)	(0.032)	(0.032)	(0.034)	(0.026)	(0.025)	(0.038)	(0.033)	(0.036)	(0.042)	(0.024)
N	1,850	1,693	1,593	1,605	1,253	1,818	1,450	1,383	1,233	1,305	906	1,450
Adjusted R^2	0.57	0.64	0.64	0.62	0.63	0.74	0.49	0.67	0.66	0.64	0.65	0.74

Note: * p<0.1, ** p<0.05, *** p<0.01
Dependent variable is the log of annual crop yield (tons per hectare) for each included country from 1961 to 2010. Crop yield data are from FAOStat. "All SSA" columns include all Sub-Saharan African countries in the FAOStat database, whereas "DHS SSA Only" columns include the SSA countries with DHS surveys in our main analysis. Columns labeled "Average" have the dependent variable as the log of the sum of the total production of main crops reported (maize, sorghum, millet, rice, and wheat) divided by the total area harvested for those crops. The crops (except for "Average") are sorted by total production, averaged across the available years, from the most to the least. Robust standard errors (in parentheses) are clustered at the country level. All regression specifications include year and country fixed effects.

Table 3: Weather Shocks and Crop Yields in India

	(1) Rice	(2) Wheat	(3) Jowar	(4) Maize	(5) Bajra	(6) Average
Drought	-0.18***	-0.048***	-0.18***	-0.041**	-0.19***	-0.16***
	(0.018)	(0.013)	(0.021)	(0.017)	(0.025)	(0.016)
N	8,208	7,670	7,118	7,563	6,054	8,672
Adjusted R^2	0.66	0.69	0.59	0.35	0.56	0.75

Note: * p<0.1, ** p<0.05, *** p<0.01
Dependent variable is the log of annual crop yield (tons per hectare) for each district from 1957 to 1987. Crop yield data are from the World Bank India Agriculture and Climate Dataset. The column labeled "Average" has the dependent variable as the log of the sum of the total production of main crops reported (rice, wheat, jowar, maize, and bajra) divided by the total area harvested for those crops. The crops (except for "Average") are sorted by total production, averaged across the available years, from the most to the least. Robust standard errors (in parentheses) are clustered at the district level. All regression specifications include year and district fixed effects.

Table 4: 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

Notes: 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 5: 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	0.0095	-0.017**	-0.010	-0.0011	0.0086
	(0.0099)	(0.0076)	(0.0077)	(0.0087)	(0.14)
Birth Year FE	Yes	Yes	Yes	Yes	Yes
Marriage Year FE	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	No	No	No
N	70,901	69,860	34,869	15,094	14,976
Adjusted R^2	0.16	0.088	0.16	0.12	0.073
Mean of Dep. Var.	0.43	0.14	0.13	0.13	3.36

Note: * p<0.1, ** p<0.05, *** p<0.01
Results for SSA countries with high prevalence of bride price (BP) custom and for India. Robust 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. Results are weighted to be representative of the included countries.

Table 6: Effect of Drought on Early Marriages

	SSA			India: DHS		India: DHS and IHDS	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Drought	0.0027***	0.0026***	0.0020**	-0.0038***	-0.0036**	-0.0069***	-0.0071***
	(0.00096)	(0.00096)	(0.00095)	(0.0014)	(0.0014)	(0.0018)	(0.0019)
Birth Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Age FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	No	Yes	Yes	No	No	No	No
Country FE × Cohort FE	No	No	Yes	No	No	No	No
District FE × Cohort FE	No	No	No	No	Yes	No	Yes
N	2,447,982	2,447,982	2,447,982	486,278	486,278	674,819	674,819
Adjusted R^2	0.076	0.076	0.077	0.10	0.10	0.10	0.10

Note: * p<0.1, ** p<0.05, *** p<0.01
Table shows OLS regressions for the Sub-Saharan Africa (SSA) and India regression samples: women aged 25 or older at the time of interview. Observations are at the level of person × age (from 10 to 17 or age of first marriage, whichever is earlier). Robust standard errors (in parentheses) are clustered at the grid cell level in columns 1-3 and the district level in columns 4-5. All regression specifications include grid cell (SSA) or district (India) fixed effects. Results are weighted to be representative of the included countries (SSA) or districts (India).

Table 7: Effect of Rainfall Shocks by Quintile

	SSA	India	
	(1)	(2)	(3)
	SSA	DHS	DHS and IHDS
Bottom Quintile	0.0022***	-0.0043***	-0.0057***
	(0.00084)	(0.0012)	(0.0017)
Birth Year FE	Yes	Yes	Yes
Age FE	Yes	Yes	Yes
Country FE	Yes	No	No
N	2,447,977	485,757	674,298
Adjusted R^2	0.076	0.10	0.10

Note: * p<0.1, ** p<0.05, *** p<0.01
Table shows OLS regressions for the Sub-Saharan Africa (SSA) high bride price (BP) and India regression samples: women aged 25 or older at the time of interview. Observations are at the level of person $\times$ age (from 10 to 17 or age of first marriage, whichever is earlier). Robust standard errors (in parentheses) are clustered at the grid cell level (SSA) or district level (India). All regression specifications include grid cell (SSA) or district (India) fixed effects. Results are weighted to be representative of the included countries (SSA) or districts (India).

Table 8: Association Between Rainfall levels and Early Marriages

	SSA			India: DHS		India: DHS and IHDS	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Rainfall (m)	-0.0076***	-0.0075***	-0.0064***	0.0021	0.0027	0.0056**	0.0066**
	(0.0017)	(0.0017)	(0.0017)	(0.0016)	(0.0017)	(0.0024)	(0.0026)
Birth Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Age FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	No	Yes	Yes	No	No	No	No
Country FE × Cohort FE	No	No	Yes	No	No	No	No
District FE × Cohort FE	No	No	No	No	Yes	No	Yes
N	2,447,982	2,447,982	2,447,982	486,278	486,278	674,819	674,819
Adjusted R^2	0.076	0.076	0.077	0.10	0.10	0.10	0.10

Note: * $p<0.1$, ** $p<0.05$, *** $p<0.01$
Table shows OLS regressions for the Sub-Saharan Africa (SSA) and India regression samples: women aged 25 or older at the time of interview. Observations are at the level of person × age (from 10 to 17 or age of first marriage, whichever is earlier). Robust standard errors (in parentheses) are clustered at the grid cell level in columns 1-3 and the district level in columns 4-5. All regression specifications include grid cell (SSA) or district (India) fixed effects. Results are weighted to be representative of the included countries (SSA) or districts (India).

Table 9: Floods and Early Marriages

	SSA		India: DHS		India: DHS and IHDS	
	(1)	(2)	(3)	(4)	(5)	(6)
Drought	0.0023**	0.0023**	-0.0037***	-0.0086***	-0.0072***	-0.0068**
	(0.00096)	(0.00096)	(0.0012)	(0.0027)	(0.0018)	(0.0027)
Flood	-0.0025**	-0.0026**	-0.0038***	-0.0074***	-0.0013	-0.0042
	(0.0011)	(0.0011)	(0.0012)	(0.0024)	(0.0020)	(0.0033)
Drought × Rice share				0.0030		-0.00071
				(0.0043)		(0.0051)
Flood × Rice share				0.0083*		0.0087
				(0.0043)		(0.0060)
Birth Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Age FE	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	No	Yes	No	No	No	No
N	2,447,982	2,447,982	486,278	257,289	674,819	365,695
Adjusted R^2	0.076	0.076	0.096	0.11	0.10	0.10

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 10 to 17 or age of first marriage, whichever is earlier). Robust 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. All regression specifications include grid cell fixed effects (SSA) or district fixed effects (India). Results are weighted to be representative of the included surveys.

Table 10: Robustness to sample specification

	SSA		India	
	(1)	(2)	(3)	(4)
	No Survey Weights	Most Recent Survey per Country	No Survey Weights	Most Recent Survey per Country
Drought	0.0017***	0.0026**	-0.0033***	-0.0097***
	(0.00049)	(0.0011)	(0.0010)	(0.0028)
Birth Year FE	Yes	Yes	Yes	Yes
Age FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	No	No
N	2,454,217	1,268,086	674,819	188,541
Adjusted R^2	0.074	0.070	0.093	0.11

Note: * p<0.1, ** p<0.05, *** p<0.01
Table shows OLS regressions with different weight and sample specifications for the high bride price (BP) Sub-Saharan Africa (SSA) and full India regression samples: women aged 25 or older at the time of interview. Observations are at the level of person × age (from 10 to 17 or age of first marriage, whichever is earlier). Robust standard errors (in parentheses) are clustered at the grid cell level (SSA) or district level (India). All regression specifications include grid cell (SSA) or district (India) fixed effects. Results are weighted to be representative of the included countries (SSA) or districts (India).

Table 11: Effect of Weather Shocks on Early Fertility in Sub-Saharan-Africa and India

	SSA			India: DHS		India: DHS and IHDS	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Drought	0.0019***	0.0019***	0.0015**	0.00067	0.00057	-0.00047	-0.00053
	(0.00074)	(0.00074)	(0.00073)	(0.00049)	(0.00051)	(0.00053)	(0.00055)
Birth Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Age FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	No	Yes	Yes	No	No	No	No
Country FE × Cohort FE	No	No	Yes	No	No	No	No
District FE × Cohort FE	No	No	No	No	Yes	No	Yes
N	2,449,401	2,449,401	2,449,401	442,362	442,362	623,661	623,661
Adjusted R^2	0.060	0.061	0.061	0.021	0.022	0.018	0.019

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 10 to 17 or age of first marriage, whichever is earlier). 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). Results are weighted to be representative of the included countries.

Table 12: Effect of Drought on Early Marriages, by Bride Price Custom in Sub-Saharan-Africa

	BP $<$ 50%		BP $\geq$ 50%		BP $\geq$ 80%	
	(1)	(2)	(3)	(4)	(5)	(6)
Drought	-0.00083	-0.00083	0.0028***	0.0028***	0.0030***	0.0029***
	(0.0015)	(0.0015)	(0.0010)	(0.0010)	(0.0011)	(0.0011)
Birth Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Age FE	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	No	Yes	No	Yes	No	Yes
N	397,863	397,863	2,050,119	2,050,119	1,721,283	1,721,283
Adjusted R^2	0.074	0.074	0.077	0.077	0.077	0.077

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. 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, defined based on thresholds of 50% (columns 2-3) and 80% (columns 4-5). Observations are at the level of person $\times$ age (from 10 to 17 or age of first marriage, whichever is earlier). Robust standard errors (in parentheses) are clustered at the grid cell level. All regression specifications include grid cell fixed effects. Results are weighted to be representative of the included countries. See Table A4 for traditional marriage customs by country.

Table 13: Effect of Drought on Early Marriages, by Religion in India

	DHS		DHS and IHDS	
	(1)	(2)	(3)	(4)
Drought × Hindu	-0.0043***	-0.0039**	-0.0081***	-0.0083***
	(0.0015)	(0.0016)	(0.0022)	(0.0022)
Drought × Not hindu	-0.0017	-0.0024	-0.0031	-0.0027
	(0.0023)	(0.0023)	(0.0034)	(0.0034)
Birth Year FE × Hindu FE	Yes	Yes	Yes	Yes
Age FE × Hindu FE	Yes	Yes	Yes	Yes
District FE × Cohort FE	No	Yes	No	Yes
N	462,112	462,112	650,653	650,653
Adjusted R^2	0.10	0.10	0.10	0.11

Note: * p<0.1, ** p<0.05, *** p<0.01
Table shows OLS regressions for India: women aged 25 or older at the time of interview. Observations are at the level of person × age (from 10 to 17 or age of first marriage, whichever is earlier). Robust standard errors (in parentheses) are clustered at the district level. All regression specifications include district fixed effects. Results in columns 3 and 4 are weighted to be representative of the included surveys.

Table 14: Marriage characteristics by rainfall realization at the time of marriage in Sub-Saharan Africa

	(1) no edu	(2) husb no edu	(3) age gap	(4) polygyny	(5) wife rank	(6) no say
Drought	0.013**	-0.00055	-0.26*	0.0097	-0.025*	0.066***
	(0.0058)	(0.0057)	(0.14)	(0.0084)	(0.014)	(0.024)
Birth Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Marriage Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
N	115,504	104,447	97,357	97,898	41,604	115,504
Adjusted R^2	0.49	0.49	0.14	0.15	0.050	0.38
Mean of Dep. Var.	0.59	0.52	11.0	0.39	0.51	1.34

Note: * p<0.1, ** p<0.05, *** p<0.01
Results for SSA countries with high prevalence of bride price (BP) custom. Robust standard errors (in parentheses) are clustered at the grid cell level. All regression specifications include grid cell fixed effects. Results are weighted to be representative of the included countries.

Table 15: Marriage characteristics by rainfall realization at the time of marriage in India

	(1)	(2)	(3)	(4)	(5)
	no edu	husb no edu	age gap	no say (DHS)	no say (IHDS)
Drought	0.0044	-0.0019	0.11	-0.025	-0.029
	(0.0065)	(0.0074)	(0.090)	(0.019)	(0.032)
Birth Year FE	Yes	Yes	Yes	Yes	Yes
Marriage Year FE	Yes	Yes	Yes	Yes	Yes
N	35,932	35,850	32,982	35,942	15,152
Adjusted R^2	0.16	0.087	0.082	0.12	0.14
Mean of Dep. Var.	0.63	0.34	6.39	1.22	3.88

Note: * $p<0.1$, ** $p<0.05$, *** $p<0.01$
Data from the 1998 India DHS (columns 1, 2, 3 and 4) and 2005 IHDS (columns 1, 2, 3 and 5). Robust standard errors (in parentheses) are clustered at the district level. All regression specifications include district fixed effects.

Table 16: Weather Shocks and Dowry Payments by Child Brides' Families

	(1) Level	(2) Level	(3) Level	(4) Level	(5) Log	(6) Log	(7) Log	(8) Log
Drought	-20575.9	-21021.4	-24451.8*	-24060.5*	-0.18**	-0.19*	-0.23**	-0.21**
	(13253.5)	(13800.5)	(13399.6)	(13820.9)	(0.088)	(0.096)	(0.095)	(0.097)
Marriage Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bride's age FE	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Groom's age FE	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Spouses' education	No	No	Yes	Yes	No	No	Yes	Yes
Parents' education	No	No	No	Yes	No	No	No	Yes
N	1,993	1,951	1,951	1,949	1,790	1,772	1,772	1,770
Adjusted R^2	0.33	0.33	0.35	0.35	0.46	0.46	0.51	0.52

Note: * p<0.1, ** p<0.05, *** p<0.01
Table shows OLS regressions based on deck 8 of the REDS data. Observations are at the level of a marriage. Robust standard errors (in parentheses) are clustered at the district level. All regression specifications include district fixed effects. Results are weighted to be representative of the included surveys.

Table 17: Summary Statistics for Regression Samples: Indonesia

	Obs.	Mean	Std. Dev.	Obs.	Mean	Std. Dev.
Panel A: Full Sample						
Unique Individuals in Sample	7,532					
Percent Married Between Ages 10-17	56,295	4.19	20.05			
Percent Drought	56,295	17.01	37.57			
Birth Year	56,295	1,966.72	8.55			
Age	56,295	13.34	2.26			
Panel B: Sample According to Ethnographic Atlas						
	Bride Price Groups			No Bride Price Groups		
Unique Individuals in Sample	1,622			5,516		
Percent Married Between Ages 10-17	12,109	4.10	19.82	41,202	4.25	20.17
Percent Drought	12,109	24.56	43.05	41,202	14.41	35.12
Birth Year	12,109	1,966.75	8.67	41,202	1,966.74	8.52
Age	12,109	13.34	2.26	41,202	13.33	2.25

Note: Table shows summary statistics for the Indonesia regression samples: women aged 25 or older at the time of interview. Observations are at the level of person $\times$ age (from 10 to 17 or age of first marriage, whichever is earlier).

Table 18: Effect of Weather Shocks on Early Marriages, by Bride Price Custom in Indonesia

	Full Sample		Sample in EA	No BP	BP	
	(1)	(2)	(3)	(4)	(5)	(6)
Drought	0.010*	0.011*	0.011*	0.011	0.013	0.0042
	(0.0050)	(0.0051)	(0.0053)	(0.0060)	(0.0084)	(0.0062)
	[0.096]	[0.068]	[0.100]	[0.176]	[0.276]	[0.548]
Drought * virilocal						0.015***
						(0.0067)
						[0.008]
Virilocal						-0.022
						(0.027)
						[0.520]
Birth Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Age FE	Yes	Yes	Yes	Yes	Yes	Yes
Province FE × Cohort FE	No	Yes	No	No	No	No
N	56,295	56,295	53,311	41,202	12,109	12,109
Adjusted R^2	0.048	0.048	0.048	0.048	0.046	0.047

Note: * p<0.1, ** p<0.05, *** p<0.01 based on wild bootstrapped p-values.
Table shows OLS regressions for Indonesia: women aged 25 or older at the time of interview. Observations are at the level of person × age (from 10 to 17 or age of first marriage, whichever is earlier). The data is merged with Murdock's *Ethnographic Atlas* (1957). See Ashraf et al. (2016) for a description of the ethnic concordance. Robust standard errors (in parentheses) are clustered at the province level, with wild bootstrapped p-values in brackets. All regression specifications include province fixed effects.

A Appendix Tables and Figures

Table A1: List of Data Sets and Sources

Region/ Country	Data Topic	Source	Year
	Marriage	Demographic and Health Survey (DHS)	1994-2014
Sub-Saharan Africa	Crop Yield	FAOStat database	1960-2010
	Conflict	UCDP/PRIO Armed Conflict Dataset	1946-2015
	Marriage	Demographic and Health Survey (DHS)	1998-1999
	Marriage	India Human Development Survey (IHDS)	2005
India	Dowry	Rural Economic and Demographic Survey (REDS)	1998
	GPS	GADM database of Global Administrative Areas	
	Crop Yield	World Bank India Agriculture and Climate Data Set	1957-1987
Indonesia	Marriage	Indonesia Family Life Survey (IFLS)	2000-2007
	Weather	University of Delaware (UDel)	1900-2010
	Population	World Development Indicators (WDI)	1990-2012
	Crop Calendar Maps	Crop Calendar Dataset (University of Wisconsin-Madison)	

Table A2: List of Data Sets 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 A3: Timing of major conflict in our SSA sample

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

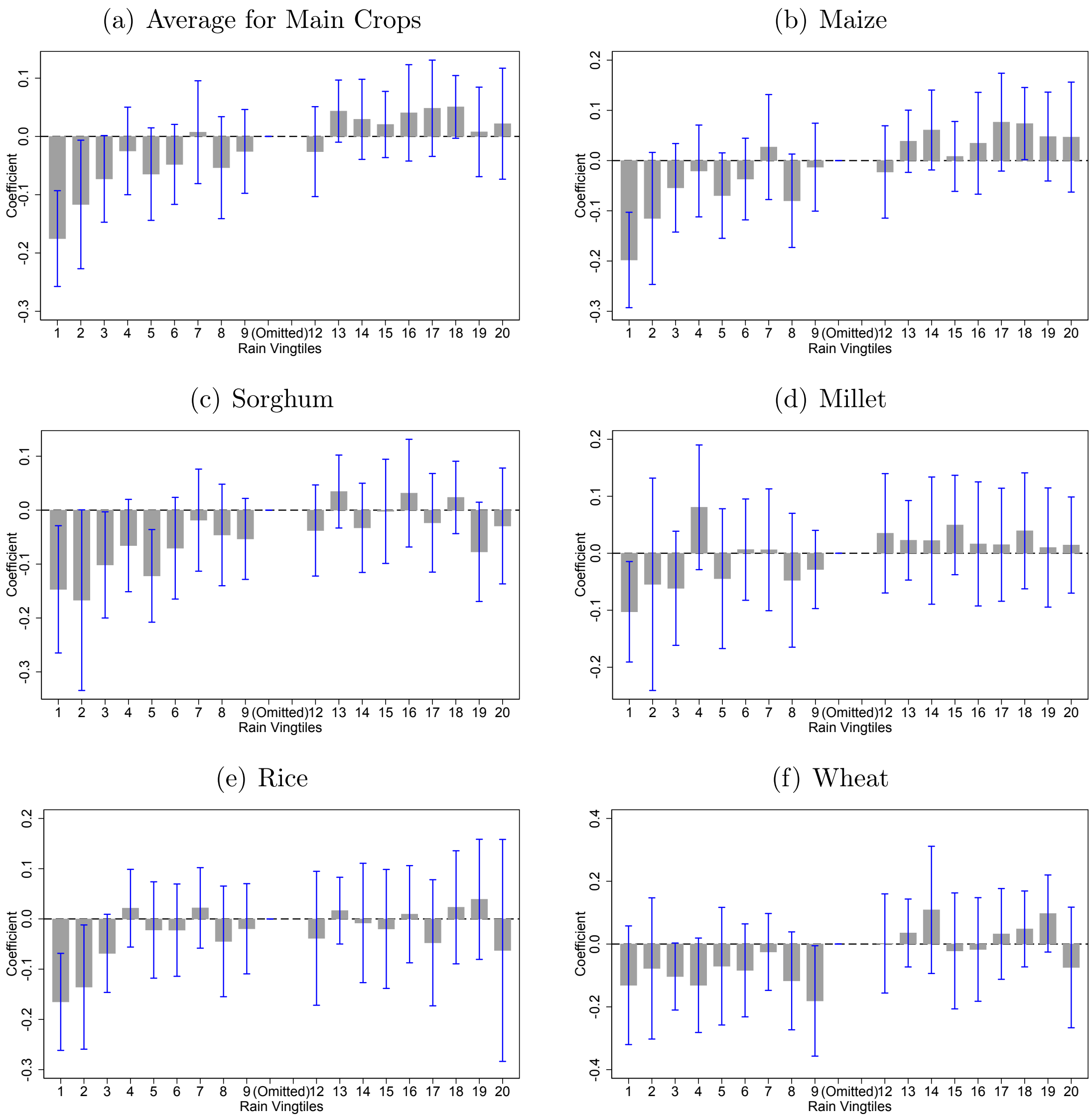
Note: Data from UCDP/PRIO Armed Conflict Dataset.

Table A4: Traditional Marriage Customs in Sub-Saharan Africa

Country	% bride price	Country	% bride price
Benin	91%	Malawi	15%
Burkina Faso	83%	Mali	93%
Burundi	99%	Mozambique	44%
Cameroon	93%	Namibia	58%
CAR	65%	Niger	100%
Congo DR	84%	Nigeria	91%
Cote d'Ivoire	69%	Rwanda	100%
Ethiopia	66%	Senegal	98%
Gabon	74%	Sierra Leone	99%
Ghana	94%	Swaziland	97%
Guinea	94%	Tanzania	81%
Kenya	100%	Togo	62%
Lesotho	100%	Uganda	97%
Liberia	98%	Zambia	19%
Madagascar	13%	Zimbabwe	87%

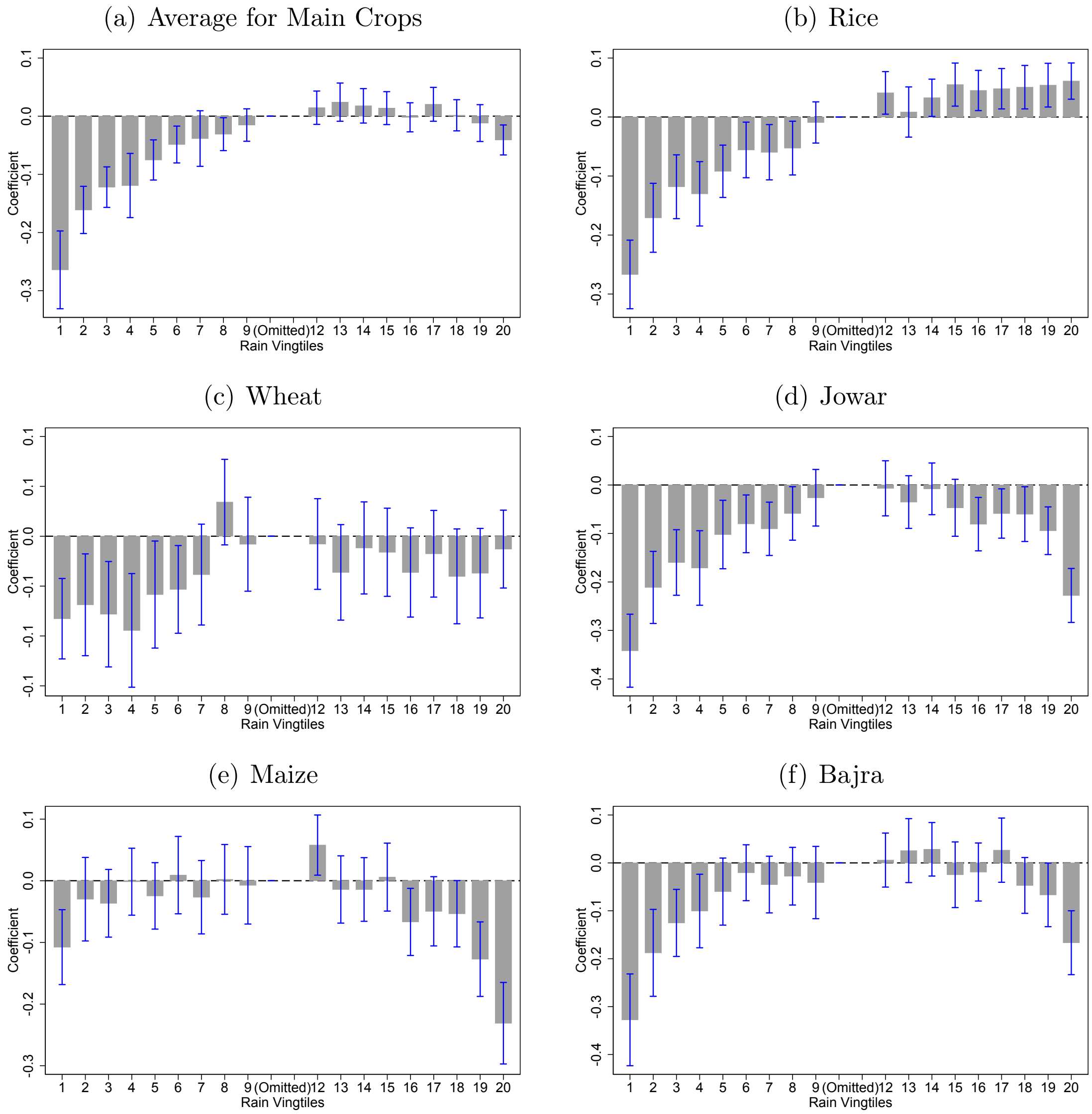
Note: Data from Ethnomaps (available at http://www.ethnomaps.ch/hpm-e/atlas-e.html, accessed February 7, 2016).

Figure A1: Crop Yields and Rainfall Vingtiles in Sub-Saharan Africa



Note: Figure 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. The sample consists of SSA countries with DHS surveys in our main analysis. The "Average for Main Crops" panel has the dependent variable as the log of the sum of the total production of main crops reported (maize, wheat, sorghum, millet, and rice) divided by the total area harvested for those crops. The individual crop figures are sorted by total production, averaged across the available years, from the most to the least. All regression specifications include year and country fixed effects. The capped vertical bars show 95% confidence intervals calculated using robust standard errors clustered at the country level.

Figure A2: Crop Yields and Rainfall Vingtiles in India



Note: Figure 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. The "Average for Main Crops" panel has the dependent variable as the log of the sum of the total production of main crops reported (rice, maize, wheat, bajra, and jowar) divided by the total area harvested for those crops. The individual crop figures are sorted by total production, averaged across the available years, from the most to the least. All regression specifications include year and district fixed effects. The capped vertical bars show 95% confidence intervals calculated using robust standard errors clustered at the district level.

Table A5: Effect of Drought on Early Marriages (Extended Upper Age Cutoff)

	SSA			India: DHS		India: DHS and IHDS	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Drought	0.0035***	0.0035***	0.0031***	-0.0060***	-0.0061***	-0.0029**	-0.0029*
	(0.00099)	(0.00099)	(0.00097)	(0.0018)	(0.0018)	(0.0014)	(0.0015)
Birth Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Age FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	No	Yes	Yes	No	No	No	No
Country FE × Cohort FE	No	No	Yes	No	No	No	No
District FE × Cohort FE	No	No	No	No	Yes	No	Yes
N	3,236,694	3,236,694	3,236,694	838,846	838,846	610,669	610,669
Adjusted R^2	0.073	0.073	0.074	0.11	0.12	0.11	0.11

Note: * p<0.1, ** p<0.05, *** p<0.01
Table shows OLS regressions for the full Sub-Saharan Africa (SSA) and India regression samples: women aged 25 or older at the time of interview. Observations are at the level of person × age (from 10 to 24 or age of first marriage, whichever is earlier). Robust standard errors (in parentheses) are clustered at the grid cell level in columns 1-3 and the district level in columns 4-5. All regression specifications include grid cell (SSA) or district (India) fixed effects. Results are weighted to be representative of the included countries (SSA) or districts (India).

Table A6: Effect of Weather Shocks on Early Marriages in Zambia, by Traditional Bride Price Practice of the Ethnic Group

	(1) Zambia	(2) Zambia in EA	(3) Zambia, no BP	(4) Zambia, BP
Drought	0.00096	0.00096	0.00026	0.0028
	(0.0015)	(0.0015)	(0.0019)	(0.0026)
Birth Year FE	Yes	Yes	Yes	Yes
Age FE	Yes	Yes	Yes	Yes
N	202,554	202,554	148,703	53,851
Adjusted R^2	0.082	0.082	0.080	0.090

Note: * p<0.1, ** p<0.05, *** p<0.01
Table shows OLS regressions for Zambia: women aged 25 or older at the time of interview. Observations are at the level of person × age (from 10 to 17 or age of first marriage, whichever is earlier). The data is merged with Murdock's *Ethnographic Atlas* (1957). See Ashraf et al. (2016) for a description of the ethnic concordance. Robust standard errors (in parentheses) are clustered at the grid cell level. All regression specifications include grid cell fixed effects. Results are weighted to be representative of the included countries.

Table A7: Weather Shocks and Bride Price Payments by Child Brides' Families in Indonesia

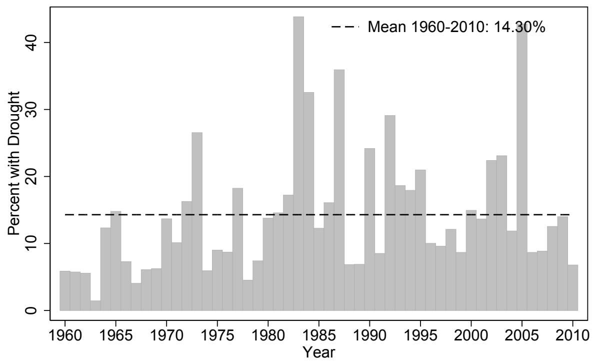
	(1) Level	(2) Level	(3) Level	(4) Log	(5) Log	(6) Log
Drought	-110917.7	-87505.2	37484.6	-0.039	-0.023	-0.0038
	(112866.2)	(101149.1)	(58293.4)	(0.11)	(0.11)	(0.094)
Marriage Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Bride's age FE	No	Yes	Yes	No	Yes	Yes
Bride's education	No	No	Yes	No	No	Yes
N	2,119	2,119	1,834	2,119	2,119	1,834
Adjusted R^2	0.14	0.22	0.17	0.80	0.80	0.79

Note: * p<0.1, ** p<0.05, *** p<0.01
Table shows OLS regressions based on IFLS data. Bride price amounts multiplied by 100000. Observations are at the level of a marriage. Robust standard errors (in parentheses) are clustered at the province level. All regression specifications include province fixed effects.

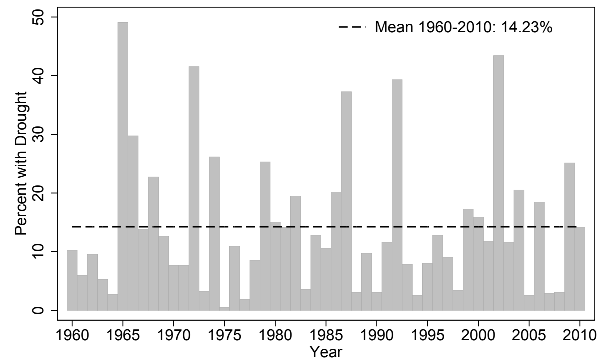
B Distribution of Weather Shocks over time

Figure B1: 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 15th percentile of the long-run rainfall distribution. The black dashed line shows the mean of drought in each sub-figure from 1960-2010.

C Theoretical appendix

C.1 Proofs

Proof of proposition 1 The derivatives of equilibrium quantities in the two economies with respect to income are equal to

$$\frac{\partial Q(y_1)^{SSA}}{\partial y_1} = \frac{2 - H^f - H^m}{H^f - H^m} \qquad \frac{\partial Q(y_1)^{IND}}{\partial y_1} = \frac{2 - H^f - H^m}{H^m - H^f}.$$

In both economies, the sign of the derivative is equal to the sign of the term $2 - H^f - H^m$. This means that, when $\tau_2^* > 0$ (sub-Saharan Africa) we can expect low income to lead to more marriages whenever $2 - H^f - H^m < 0$ or $\frac{1}{H^f - 1} < -\frac{1}{H^m - 1}$. When $\tau_2^* < 0$ (India), we can expect low income to lead to fewer marriages whenever $2 - H^f - H^m > 0$, or that $-\frac{1}{H^f - 1} < \frac{1}{H^m - 1}$.

Note that $\frac{\partial H^m}{\partial w^m} = exp(\Omega^m)\frac{\partial \Omega^m}{\partial w}$ and that

$$\frac{\partial \Omega^m}{\partial w} = \left\{ \delta \sum_{s \in \{L,H\}} \pi_s \left[ln\left(\frac{y_s + 1 + w^m + w^f - \tau}{y_s + w^m + w^f - \tau}\right) - ln\left(\frac{y_s + 1 + w^m + w^f}{y_s + w^m + w^f}\right)\right]\right\}.$$

In the case of SSA, with $\tau > 0$, H_m is increasing in w^m: again, when w^m is larger, the inequality is more likely to be satisfied. In the case of India, where $\tau < 0$ H_m is decreasing in w^m: again, when w^m is larger, the inequality is more likely to be satisfied.

Proof of proposition 2 The derivative with respect to income is

$$\frac{\partial \tau_1^*(y_1)}{\partial y_1} = 2\frac{(1 - H^f)(1 - H^m)}{H^m - H^f}.$$

This derivative is positive when transfers are positive (i.e. bride price payments are higher when income is higher), i.e. when $H^f > 1$ and $H^m < 1$. It is negative, instead, when transfers are negative (i.e. dowry payments, which are $-\tau_1^*$, are also higher when income is higher), i.e. when $H^f < 1$ and $H^m > 1$.

C.2 Incorporating child labor

We now consider the case in which children provide labor, either on their parents' farm or in the market, and children's wages w_1, are affected by aggregate shocks. In particular, we will assume that child labor is negatively affected by droughts: $\frac{dw_1(y_1)}{dy_1} \geq 0$).

Under these conditions, a woman from household i will get married in the first period if and only if:

$$ln(y_1 + \epsilon_1^i + \tau_1) - ln(y_1 + \epsilon_1^i + w_1) \geq \Omega^f$$

In SSA the supply of brides, defined on the $[0, 1]$ interval, takes the form

$$S^{SSA}(y_1, \tau_1) = \frac{\tau_1}{H^f - 1} - y_1 - \frac{H^f w_1}{H^f - 1}.$$

Note that $S_\tau^{SSA}(y_1, \tau_1)$ is unchanged, while $S_y^{SSA}(y_1, \tau_1) = -1 - \frac{H^f}{H^f - 1}\frac{dw_1(y_1)}{dy_1} < 0$.

Similarly, under these conditions, a man from household i will get married in the first period if and only if:

$$ln(y_1 + \epsilon_1^j - \tau_1 + 2w_1) - ln(y_1 + \epsilon_1^j + w_1) \geq \Omega^f.$$

Hence, the demand for brides becomes

$$D^{SSA}(y_1, \tau_1) = 1 + y_1 + \frac{\tau_1}{H^m - 1} + \frac{H^m - 2}{H^m - 1} w_1.$$

Again, the derivative with respect to prices is unchanged, while $D_y^{SSA}(y_1, \tau_1) = 1 + \frac{H^m-2}{H^m-1}\frac{dw_1(y_1)}{dy_1} > 0$.

In India, the supply of brides, defined on the $[0, 1]$ interval, takes the form

$$S^{IND}(y_1, \tau_1) = 1 - \frac{\tau_1}{H^f - 1} + y_1 + \frac{H^f w_1}{H^f - 1}.$$

Here, $S_y^{IND}(y_1, \tau_1) = 1 + \frac{H^f}{H^f-1}\frac{dw_1(y_1)}{dy_1}$, which cannot be signed: droughts reduce parent's ability to pay dowry, but also makes a child daughter's labor less valuable to the household.

The demand for brides becomes

$$D^{IND}(y_1, \tau_1) = -y_1 - \frac{\tau_1}{H^m - 1} - \frac{H^m - 2}{H^m - 1} w_1.$$

Again, the derivative with respect to prices is unchanged, while $D_y^{IND}(y_1, \tau_1) = -1 - \frac{H^m-2}{H^m-1}\frac{dw_1(y_1)}{dy_1}$.

Equilibrium quantities are :

$$\begin{aligned} Q(y_1)^{SSA} &= \frac{2 - H^f - H^m}{H^f - H^m}(y_1 + w_1) - \frac{H^m - 1}{H^f - H^m}, \\ Q(y_1)^{IND} &= \frac{2 - H^f - H^m}{H^m - H^f}(y_1 + w_1) - \frac{H^f - 1}{H^m - H^f}. \end{aligned}$$

The derivatives of these quantities with respect to aggregate income are

$$\begin{aligned} \frac{\partial Q(y_1)^{SSA}}{\partial y_1} &= \frac{2 - H^f - H^m}{H^f - H^m}\left(1 + \frac{dw_1(y_1)}{dy_1}\right) \\ \frac{\partial Q(y_1)^{IND}}{\partial y_1} &= \frac{2 - H^f - H^m}{H^m - H^f}\left(1 + \frac{dw_1(y_1)}{dy_1}\right). \end{aligned}$$

Hence, as long as $\frac{dw_1(y_1)}{dy_1} \geq 0$, the proof of proposition 1 continues to hold and the effect of drought on the quantity of child marriages is stronger. This effect happens because families of boys are affected less strongly by the drought even in the first period, because they can rely on their child son's labor even if he gets married.

Equilibrium marriage payments are

$$\tau_1^*(y_1) = \frac{(H^f - 1)(H^m - 1)}{H^m - H^f}(1 + 2y_1) + \left(2H^f - \frac{H^m - 2}{H^m - H^f}\right) w.$$

The derivative with respect to income is

$$\frac{\partial \tau_1^*(y_1)}{\partial y_1} = 2\frac{(H^f-1)(H^m-1)}{H^m-H^f} + \left(2H^f - \frac{H^m-2}{H^m-H^f}\right)\frac{dw_1(y_1)}{dy_1}.$$

Hence, predictions about equilibrium marriage payments with child labor are ambiguous. Proposition 2 may not hold, but price effects are no longer necessary to obtain quantity effects.

C.3 Generalizing preferences and distributions

Consider general preferences represented by a function $u(\cdot)$ which is strictly increasing, strictly concave and twice-continuously differentiable. For proposition 1 to hold, we will also require that households are prudent ($u'''(\cdot) > 0$). Allow also the distribution of ϵ_t to follow a continuous distribution with pdf $f(\cdot)$ and cdf $F(\cdot)$ for both men and women.

As in the log-utility case, a woman from household i will get married in the first period if and only if:

$$u(y_1+\epsilon_1^i+\tau_1) + \delta E\left[u(y_2+\epsilon_2^i)\right] \geq u(y_1+\epsilon_1^i) + \delta E\left[u(y_2+\epsilon_2^i+\tau_2^*)\right]$$

Similarly, a man from household j will get married in the first period if and only if:

$$\begin{aligned}&u(y_1+\epsilon_1^j-\tau_1) + \delta E\left[u(y_2+\epsilon_2^j+w^m+w^f)\right] \geq \\ &u(y_1+\epsilon_1^j) + \delta E\left[u(y_2+\epsilon_2^j+w^m+w^f-\tau_2^*)\right].\end{aligned}$$

Consider now the income thresholds ϵ_f^* and ϵ_m^* at which the above expressions hold with equality:

$$\begin{aligned}u(y_1+\epsilon_1^{f*}+\tau_1) - u(y_1+\epsilon_1^{f*}) &= \Omega^f \\ u(y_1+\epsilon^{m*}-\tau_1) - u(y_1+\epsilon^{m*}) &= \Omega^m.\end{aligned}$$

Define $\Omega^f = \delta E\left[u(y_2+\epsilon_2^i+\tau_2^*)\right] - \delta E\left[u(y_2+\epsilon_2^i)\right]$ and $\Omega^m = \delta E\left[u(y_2+\epsilon_2^j+w^m+w^f-\tau_2^*)\right] - \delta E\left[u(y_2+\epsilon_2^j+w^m+w^f)\right]$. Applying the implicit function theorem (IFT) and the chain rule, we have that

$$\begin{aligned}\frac{\partial \epsilon_f^*(\tau_1,y_1,\Omega^f)}{\partial \tau_1} &= -\frac{u'(y_1+\epsilon_f^*+\tau_1)}{u'(y_1+\epsilon_f^*+\tau_1)-u'(y_1+\epsilon_f^*)} \\ \frac{\partial \epsilon_f^*(\tau_1,y_1,\Omega^f)}{\partial y_1} &= -\frac{u'(y_1+\epsilon_f^*+\tau_1)-u'(y_1+\epsilon_f^*)}{u'(y_1+\epsilon_f^*+\tau_1)-u'(y_1+\epsilon_f^*)} = -1 \\ \frac{\partial \epsilon_m^*(\tau_1,y_1,\Omega^m)}{\partial \tau_1} &= \frac{u'(y_1+\epsilon_m^*-\tau_1)}{u'(y_1+\epsilon_m^*-\tau_1)-u'(y_1+\epsilon_m^*)} \\ \frac{\partial \epsilon_m^*(\tau_1,y_1,\Omega^m)}{\partial y_1} &= -\frac{u'(y_1+\epsilon_m^*-\tau_1)-u'(y_1+\epsilon_m^*)}{u'(y_1+\epsilon_m^*-\tau_1)-u'(y_1+\epsilon_m^*)} = -1.\end{aligned}$$

Sub-Saharan Africa Monotonicity and concavity of the utility function, as well as the fact that continuation values do not depend on ϵ_1^i, imply that below threshold ϵ_f^* every household wants their daughter to be married, *ceteris paribus*. This implies that the supply of brides is defined in SSA as:

$$S^{SSA}(\tau_1, y_1, \Omega^f) = Prob(\epsilon_t^i < \epsilon_f^*(\tau_1, y_1, \Omega^f)) = F(\epsilon_f^*(\tau_1, y_1, \Omega^f)).$$

Concavity ensures that $\frac{\partial \epsilon_f^*(\tau_1, y_1, \Omega^f)}{\partial \tau_1} > 0$.

The above conditions, together with the chain rule and the fact that $F'(\cdot) = f(\cdot) > 0$, also imply that

$$\frac{\partial S^{SSA}(\tau_1, y_1, \Omega^f)}{\partial \tau_1} = S_\tau^{SSA}(\tau_1, y_1, \Omega^f) = f(\epsilon_f^*(\tau_1, y_1, \Omega^f)) \frac{\partial \epsilon_f^*(\tau_1, y_1, \Omega^f)}{\partial \tau_1} > 0$$
$$\frac{\partial S^{SSA}(\tau_1, y_1, \Omega^f)}{\partial y_1} = S_y^{SSA}(\tau_1, y_1, \Omega^f) = -f(\epsilon_f^*(\tau_1, y_1, \Omega^f)) < 0.$$

A similar argument would lead us to show that the demand for brides is

$$D^{SSA}(\tau_1, y_1, \Omega^m) = Prob(\epsilon_i \geq \epsilon_m^*(\tau_1, y_1, \Omega^m)) = 1 - F(\epsilon_m^*(\tau_1, y_1, \Omega^m))$$

and the derivative of the threshold with respect to the marriage payment is $\frac{\partial \epsilon_m^*(\tau_1, y_1, \Omega^m)}{\partial \tau_1} > 0$. Hence, because of continuity and the chain rule

$$\frac{\partial D^{SSA}(\tau_1, y_1, \Omega^m)}{\partial \tau_1} = D_\tau^{SSA}(\tau_1, y_1, \Omega^m) = -f(\epsilon_m^*(\tau_1, y_1, \Omega^m)) \frac{\partial \epsilon_m^*(\tau_1, y_1, \Omega^m)}{\partial \tau_1} < 0$$
$$\frac{\partial D^{SSA}(\tau_1, y_1, \Omega^m)}{\partial y_1} = D_y^{SSA}(\tau_1, y_1, \Omega^m) = f(\epsilon_m^*(\tau_1, y_1, \Omega^m)) > 0.$$

India The same arguments used above, when transfers are negative, would lead us to conclude that $\frac{\partial \epsilon_f^*(\tau_1, y_1, \Omega^f)}{\partial \tau_1} < 0$ and $\frac{\partial \epsilon_m^*(\tau_1, y_1, \Omega^m)}{\partial \tau_1} < 0$. Hence

$$S^{IND}(\tau_1, y_1, \Omega^f) = Prob(\epsilon_i \geq \epsilon_f^*(\tau_1, y_1, \Omega^f)) = 1 - F(\epsilon_f^*(\tau_1, y_1, \Omega^f))$$
$$D^{IND}(\tau_1, y_1, \Omega^m) = Prob(\epsilon_i < \epsilon_m^*(\tau_1, y_1, \Omega^m)) = F(\epsilon_m^*(\tau_1, y_1, \Omega^m)).$$

The derivatives are the following:

$$\frac{\partial S^{IND}(\tau_1, y_1, \Omega^f)}{\partial \tau_1} = S_\tau^{IND}(\tau_1, y_1, \Omega^f) = -f(\epsilon_f^*(\tau_1, y_1, \Omega^f)) \frac{\partial \epsilon_f^*(\tau_1, y_1, \Omega^f)}{\partial \tau_1} > 0$$
$$\frac{\partial S^{IND}(\tau_1, y_1, \Omega^f)}{\partial y_1} = S_y^{IND}(\tau_1, y_1, \Omega^f) = f(\epsilon_f^*(\tau_1, y_1, \Omega^f)) > 0$$
$$\frac{\partial D^{IND}(\tau_1, y_1, \Omega^m)}{\partial \tau_1} = D_\tau^{IND}(\tau_1, y_1, \Omega^m) = f(\epsilon_m^*(\tau_1, y_1, \Omega^m)) \frac{\partial \epsilon_m^*(\tau_1, y_1, \Omega^m)}{\partial \tau_1} < 0$$
$$\frac{\partial D^{IND}(\tau_1, y_1, \Omega^m)}{\partial y_1} = D_y^{IND}(\tau_1, y_1, \Omega^m) = -f(\epsilon_m^*(\tau_1, y_1, \Omega^m)) < 0.$$

Equilibrium In both economies, equilibrium prices are defined implicitly as the solution to

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

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

$$\frac{\partial \tau_1^*}{\partial y_1} = -\frac{S_y(\tau_1, y_1, \Omega^f) - D_y(\tau_1, y_1, \Omega^m)}{S_\tau(\tau_1, y_1, \Omega^f) - D_\tau(\tau_1, y_1, \Omega^m)}.$$

This derivative is positive in SSA and negative in India (as stated in proposition 2).

Define now $\tau = S^{-1}(q_1, y_1, \Omega^f)$ as an inverse supply function and $\tau = D^{-1}(q_1, y_1, \Omega^m)$ as an inverse demand function. Note that $S_q^{-1}(q, y_1, \Omega^f)$ and $D_q^{-1}(q, y_1, \Omega^m)$ have the same sign as $S_\tau(\tau_1, y_1, \Omega^f)$ (positive) and $D_\tau(\tau_1, y_1, \Omega^m)$ (negative), respectively. Moreover, $S_y^{-1}(q, y_1, \Omega^f) = -\frac{S_y(\tau_1, y_1, \Omega^f)}{S_\tau(\tau_1, y_1, \Omega^f)}$ is positive SSA and negative in India, as is $D_y^{-1}(q, y_1, \Omega^m) = -\frac{D_y(\tau_1, y_1, \Omega^m)}{D_\tau(\tau_1, y_1, \Omega^m)}$.[15]

In equilibrium, $D^{-1}(Q, y_1, \Omega^m) = \tau^* = S^{-1}(Q, y_1, \Omega^f)$ where Q is the equilibrium quantity of child marriage. Again the IFT allows us to derive

$$Q'(y_1) = -\frac{S_y^{-1}(Q, y_1, \Omega^f) - D_y^{-1}(Q, y_1, \Omega^m)}{S_q^{-1}(Q, y_1, \Omega^f) - D_q^{-1}(Q, y_1, \Omega^m)}.$$

The denominator of the above expression, $S_q^{-1,SSA}(Q, y_1, \Omega^f) - D_q^{-1,SSA}(Q, y_1, w^m, \Omega^m)$, is always positive.

Hence, in SSA, in order to have that $Q'(y_1) < 0$, we need that $S_y^{-1,SSA}(Q, y_1, \Omega^f) > D_y^{-1,SSA}(Q, y_1, \Omega^m)$, hence that $-\frac{S_y^{SSA}(\tau_1, y_1, \Omega^f)}{S_\tau^{SSA}(\tau_1, y_1, \Omega^f)} > -\frac{D_y^{SSA}(\tau_1, y_1, \Omega^m)}{D_\tau^{SSA}(\tau_1, y_1, \Omega^m)}$ or

$$\frac{S_y^{SSA}(\tau_1, y_1, \Omega^f)}{S_\tau^{SSA}(\tau_1, y_1, \Omega^f)} < \frac{D_y^{SSA}(\tau_1, y_1, \Omega^m)}{D_\tau^{SSA}(\tau_1, y_1, \Omega^m)}.$$

Applying the above derivations of these partial derivatives, we have that:

$$\frac{S_y^{SSA}(\tau_1, y_1, \Omega^f)}{S_\tau^{SSA}(\tau_1, y_1, \Omega^f)} = -\frac{1}{\frac{\partial \epsilon_f^*(\tau_1, y_1, \Omega^f)}{\partial \tau_1}}$$

and

$$\frac{D_y^{SSA}(\tau_1, y_1, \Omega^m)}{D_\tau^{SSA}(\tau_1, y_1, \Omega^m)} = \frac{f(\epsilon_m^*(\tau_1, y_1, \Omega^m))}{-f(\epsilon_m^*(\tau_1, y_1, \Omega^m))\frac{\partial \epsilon_m^*(\tau_1, y_1, \Omega^m)}{\partial \tau_1}} = -\frac{1}{\frac{\partial \epsilon_m^*(\tau_1, y_1, \Omega^m)}{\partial \tau_1}}.$$

Hence, the condition translates into

$$\frac{\partial \epsilon_f^*(\tau_1, y_1, \Omega^f)}{\partial \tau_1} < \frac{\partial \epsilon_m^*(\tau_1, y_1, \Omega^m)}{\partial \tau_1},$$

In India, in order to have that $Q'(y_1) > 0$, we need that $S_y^{-1,IND}(Q, y_1) < D_y^{-1,IND}(Q, y_1)$, hence that $-\frac{S_y^{IND}(\tau_1, y_1, \Omega^f)}{S_\tau^{IND}(\tau_1, y_1, \Omega^f)} < -\frac{D_y^{IND}(\tau_1, y_1, \Omega^m)}{D_\tau^{IND}(\tau_1, y_1, \Omega^m)}$ or

$$\frac{S_y^{IND}(\tau_1, y_1, \Omega^f)}{S_\tau^{IND}(\tau_1, y_1, \Omega^f)} > \frac{D_y^{IND}(\tau_1, y_1, \Omega^m)}{D_\tau^{IND}(\tau_1, y_1, \Omega^m)}.$$

[15] To see this, consider the conditions $q - S(\tau_1, y_1, \Omega^f) = 0$ and $q - D(\tau_1, y_1, \Omega^m) = 0$ and apply the IFT.

Applying the above derivations of these partial derivatives, we have that:

$$\frac{S_y^{IND}(\tau_1, y_1, \Omega^f)}{S_\tau^{IND}(\tau_1, y_1, \Omega^f)} = -\frac{1}{\frac{\partial \epsilon_f^*(\tau_1, y_1, \Omega^f)}{\partial \tau_1}}$$

and

$$\frac{D_y^{IND}(\tau_1, y_1, \Omega^m)}{D_\tau^{IND}(\tau_1, y_1, \Omega^m)} = \frac{-f(\epsilon_m^*(\tau_1, y_1, \Omega^m))}{f(\epsilon_m^*(\tau_1, y_1, \Omega^m))\frac{\partial \epsilon_m^*(\tau_1, y_1, \Omega^m)}{\partial \tau_1}} = -\frac{1}{\frac{\partial \epsilon_m^*(\tau_1, y_1, \Omega^m)}{\partial \tau_1}}.$$

Hence, the condition translates into

$$\frac{\partial \epsilon_f^*(\tau_1, y_1, \Omega^f)}{\partial \tau_1} > \frac{\partial \epsilon_m^*(\tau_1, y_1, \Omega^m)}{\partial \tau_1}.$$

As in the less general case, prudence ($u'''(\cdot) > 0$) is sufficient for these conditions to become more likely to hold when w^m (and w^f, holding τ_2^* constant) becomes larger (proposition 1).

This result can easily be shown by studying the properties of $\frac{\partial^2 \epsilon_m^*(\tau_1, y_1, \Omega^m)}{\partial \tau_1 \partial w^m}$:

$$\begin{aligned}\frac{\partial^2 \epsilon_m^*(\tau_1, y_1, \Omega^m)}{\partial \tau_1 \partial w^m} &= \frac{\partial}{\partial w^m}\left[\frac{u'(y_1 + \epsilon_m^* - \tau_1)}{u'(y_1 + \epsilon_m^* - \tau_1) - u'(y_1 + \epsilon_m^*)}\right] \\ &= \frac{\partial \epsilon_m^*}{\partial w^m}\frac{u'(y_1 + \epsilon_m^* - \tau_1)u''(y_1 + \epsilon_m^*) - u''(y_1 + \epsilon_m^* - \tau_1)u'(y_1 + \epsilon_m^*)}{[u'(y_1 + \epsilon_m^* - \tau_1) - u'(y_1 + \epsilon_m^*)]^2}.\end{aligned}$$

Now

$$\frac{\partial \epsilon_m^*}{\partial w^m} = \frac{\partial \epsilon_m^*}{\partial \Omega^m}\frac{\partial \Omega^m}{\partial w^m} = \frac{\delta E\left[u'(y_2 + \epsilon_2^j + w^m + w^f - \tau_2^*)\right] - \delta E\left[u'(y_2 + \epsilon_2^j + w^m + w^f)\right]}{u'(y_1 + \epsilon_m^* - \tau_1) - u'(y_1 + \epsilon_m^*)} > 0$$

in both SSA and in India.

Moreover, under concavity and prudence, we have that $u'(y_1 + \epsilon_m^* - \tau_1) > u'(y_1 + \epsilon_m^*)$ and $u''(y_1 + \epsilon_m^*) > u''(y_1 + \epsilon_m^* - \tau_1)$ in SSA and $u'(y_1 + \epsilon_m^* - \tau_1) < u'(y_1 + \epsilon_m^*)$ and $u''(y_1 + \epsilon_m^*) < u''(y_1 + \epsilon_m^* - \tau_1)$ in India. Hence $\frac{\partial^2 \epsilon_m^*(\tau_1, y_1, \Omega^m)}{\partial \tau_1 \partial w^m} > 0$ in SSA and $\frac{\partial^2 \epsilon_m^*(\tau_1, y_1, \Omega^m)}{\partial \tau_1 \partial w^m} < 0$ in India.