NBER WORKING PAPER SERIES

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Working Paper 23604
http://www.nber.org/papers/w23604

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
July 2017

We thank David Atkin, Natalie Bau, Marianne Bertrand, Bill Easterley, Raquel Fernandez, Luigi Guiso, Rick Hornbeck, Seema Jayachandran, Sylvie Lambert, Eliana La Ferrara, Neale Mahoney, Costas Meghir, Nathan Nunn, Yaw Nyarko, Debraj Ray, Dean Spears, Michèle Tertilt and participants in presentations at SITE, EUDN, Harvard/MIT, CEPR, AEA meetings, Università Cattolica, Columbia, UCSD, Bocconi, Stockholm and Sciences-Po for helpful comments. Yin Wei Soon provided outstanding research assistance. The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

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NBER Working Paper No. 23604
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JEL No. J1,J12,J13,O15

ABSTRACT

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

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

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

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

To test the implications of our model, we examine the effect of rainfall shocks –a major source of income variability in rural areas that rely on rain-fed agriculture– on the hazard into early marriage among women in Sub-Saharan Africa and India. We combine rainfall data from the University of Delaware Air Temperature and Precipitation project (UDel) between 1950 and 2010 with marriage information from 73 pooled Demographic and Health Surveys (DHS) from 31 Sub-Saharan African countries between 1994 and 2013, from the 1998-1999 India DHS and from the 2005 Indian Human Development Survey (IHDS). We henceforth obtain information on the age of marriage and on the history of rainfall shocks for approximately 400,000 women for every year between age 12 and age 24 born between 1950 and 1989. To investigate the effect of rainfall shocks on agricultural output, we also merge the UDel data with historical data on crop yields provided by the Food and Agricultural Organization (FAO) and by the World Bank. In both regions, a drought, defined as an annual rainfall realization below the 15th percentile of the local rainfall distribution, is associated with a significant 10 to 15% decline in agricultural production.

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

To study whether indeed the direction of marriage payments can explain these differential patterns, we examine heterogeneity between and within countries. First, we exploit historical data on heterogeneity in marriage payments across ethnic groups collected by the anthropologist George Peter Murdock for the *Ethnographic Atlas* (1967) and merged to country populations in the University of Zurich's *Ethnomaps* database. 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 where the majority of the population belongs to ethnic groups that traditionally make bride price payments at marriage. We find no effect in countries where less than half of the population traditionally engages in bride price payments. To dig deeper into the role played by marriage payments in shaping early marriage's decision, we test our main effect in Eritrea, a country within Sub-Saharan Africa where dowry is prevalent. We find a negative correlation between drought and early marriage, similar to the one documented in India. Our within-countries analysis also suggests that the ethnic groups that traditionally engage in bride price payments are the most sensitive to droughts, particularly in Zambia. Furthermore, within India, where nowadays dowry prevails across regions, casts and religious groups, we find that the effect of rainfall shocks on the hazard into early marriage is concentrated among Hindus, who have a stronger historical tradition of dowry payments. Also, within India, the effect are strongest where irrigation and banking are less developed, suggesting that reducing consumption volatility can mitigate the effects of droughts on age of marriage.

We then move to examining an important implication of child marriages: early fertility. We show that in Sub-Saharan Africa, a drought is associated with a 4 percent increase in the annual probability of having a child before turning 18. Furthermore, in countries where bride price is the most common mode of marriage, one additional drought episode every three years experienced between ages 12 and 24 reduces the age of marriage by 0.04-0.05 years and increases the total number of children a woman reports by 0.04 or 1%.

Are couples who match during droughts different from those who match outside droughts? Opposite patterns arise in the two economies. In Sub-Saharan Africa, low-educated women are more likely to marry during droughts and end up having lower decision-making power in their newly-formed family. In India, we show weak empirical evidence that high-educated women are more likely to marry during droughts and end up having higher say in household decision making. Importantly, we don't find any statistically significant difference among couples who marry during droughts in terms of likelihood of marriage migration, age gaps, husbands' education either in Sub-Saharan Africa nor in India.

Finally, we investigate whether payments for marriages that occur during droughts are indeed lower, as predicted by our model. To do so, we exploit additional available data on dowry payments in India and in Indonesia from the 1998 Rural Economic and Demographic Survey (REDS) and from the Indonesia Family Life Survey (IFLS), as no extensive data from Africa is available. In both countries, we find that transfers paid for marriages that occur during droughts are substantially lower than those paid during normal times, consistent with the predictions of our model: in India, a drought at the district level is associated with 15% lower dowry payments, while in Indonesia, a drought at the province level is associated with 45% lower bride price payments. Controlling for observable characteristics of the match does not affect these estimates, suggesting that indeed marriage payments are likely to drop with aggregate negative economic shocks.

Our paper is related to three strands of the literature in economics. The first is the literature on how marriage markets work (Abramitzky, Delavande, and Vasconcelos, 2011; Banerjee, Duflo, Ghatak, and Lafortune, 2013; Chiappori, Salanié, and Weiss, forthcoming) and how they interact with economic outcomes (Tertilt, 2005, 2006; Greenwood, Guner, and Vandenbroucke, 2017), especially in developing countries. There is only limited and generally discordant evidence about how the business cycle affects marriage behavior in developed or in developing countries (Schaller, 2013; Dorn and Hanson, 2015; Brandt, Siow, and Vogel, 2016), and more generally about how short-term changes in economic incentives influence marriage behavior. Generally, the existing empirical evidence suggests that economic forces have at best small effects on the marriage market. We contribute to this literature by showing that, where marriage payments are customary, temporary aggregate income shocks lead to substantial shifts in the timing of marriage, particularly at the crucial early ages, in the timing of fertility and in the fertility rate. These findings suggest that economic policies that modify the incentives to marry in the short run can have lasting effects on women's marital and fertility outcomes.[1]

[1] These insights are particularly valuable given increasing worldwide calls to eliminate child marriage. According to recent estimates by the World Bank, eliminating child marriage and child fertility could reduce fertility

Second, this paper fits within the broad body of research on the importance of culture and institutions in shaping economic behavior. Much of this work has studied the role of cultural values and beliefs, such as trust, family ties, and gender norms on economic development (Fernandez, Fogli, and Olivetti, 2004; Fernandez and Fogli, 2009; Guiso, Sapienza, and Zingales, 2006; Alesina, Algan, Cahuc, and Giuliano, 2010; Tabellini, 2010; Nunn and Wantchekon, 2011). A growing part of this literature has explored the influence of traditional cultural norms - behaviors that are enforced through social sanctions or rewards - on determinants of economic development (Platteau, 2000; Jacoby, 1995; Tertilt, 2005; La Ferrara, 2007; La Ferrara and Milazzo, 2017; Jayachandran and Pande, forthcoming). While marriage payments are widespread in many regions in Africa and Asia, only a few studies have examined their effect on households' economic decision, such as female education and health (Bishai and Grossbard, 2010; Anderson and Bidner, 2015; Ashraf, Bau, Nunn, and Voena, 2016; Bhalotra, Chakravarty, and Gulesci, 2016). In this paper, we show that these payments significantly influence how the marriage market works, generating opposite responses to the same economic circumstances. These findings are an example of how cultural norms may influence the external validity of natural experiments, by radically modifying the economic relationship between variables. Hence, understanding their role can contribute to policy design and evaluation: for example, our framework suggests that income stabilization policies, like crop insurance, could reduce child marriage in some countries, but increase it others. A deep understanding of the mechanism that regulate the marriage market can shed light on what the most effective policies to address child marriage in each context are. Our findings emphasize the value of replicating empirical and experimental analyses in different environments and highlight the role of cultural norms as variables that may be relevant for extrapolation (Dehejia, Pop-Eleches, and Samii, 2015).

Third, our results contribute to the large economic literature that investigates the coping mechanisms used by poor households to deal with income risk. Despite imperfect markets for formal insurance, rural households seem well-equipped to smooth consumption in the face of short-term, idiosyncratic income shocks, often through informal insurance arrangements (Townsend, 1994). However, in the face of aggregate shocks, households must rely on a different set of strategies to cope such as seasonal migration, off-farm employment, and liquidation of buffer

rates and population growth rates by 10% in high-prevalence countries, generating over $500 billion in annual benefits each years, through a reduction in deaths and malnutrition among young children and through increased female labor market earnings and productivity, among other channels (Wodon, Male, Nayihouba, et al., 2017).

stock (Morten, 2016; Jayachandran, 2006; Fafchamps, Udry, and Czukas, 1998). These strategies are typically unable to provide full consumption smoothing, as illustrated by the growing empirical literature testing the effect of rainfall shocks on individual outcomes and showing a detrimental effect of drought on infant and child health, schooling attainment and performance, and domestic violence.[2] In this paper, we show that households use female child marriage as a strategy to cope with income volatility, bringing it forward when a payment is expected and delaying it when a payment is due. The inability to smooth consumption leads households to make irreversible decisions even in response to short-term shocks, with harmful long-run welfare implications for young women and their offspring, thus contributing to gender inequality and lower accumulation of human capital.

The remainder of the paper proceeds as follows. Section 1 provides background information on marriage markets, marriage payments, and early marriage in Sub-Saharan Africa and in India. Section 2 illustrates the model. Section 3 describes the data used in the analysis, and section 4 explains the empirical and identification strategy. Sections 5 and 6 show the empirical results and provide robustness checks, while section 7 brings in additional data sources on actual bride price and dowry payments. Section 8 concludes.

1 Background

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

1.1 Age of marriage and child marriage

Early marriage is still a dramatic practice in many countries around the world. Worldwide, more than 700 million women alive today were married before their 18th birthday and 25 million entered into union before the age of 15. Child marriage, defined as marriage before the age of 18, is especially pronounced among women living in Sub-Saharan Africa and South Asia. Estimates from UNICEF suggests that 56% and 42% of women between 20 to 49 got married before the age of 18 respectively in South Asia and in Sub-Saharan Africa (UNICEF, 2014b). Early marriage

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

is associated with a wide range of adverse outcomes for women and their offspring, including higher rates of domestic violence; harmful effects on maternal, newborn, and infant health; reduced sexual and reproductive autonomy; lower literacy and educational attainment (Jensen and Thornton, 2003; Field and Ambrus, 2008; Chari, Heath, Maertens, and Fatima, 2017). Based on these findings, international organizations such as UNICEF and the World Bank have called for "urgent action", arguing that the eradication of early marriage is a necessary step towards improving female human capital accumulation, empowerment and autonomy around the world.[3] Despite the brutal consequences of early marriage and policy action taken to reduce it, the causes of this phenomena has been so far seldom examined in the economic literature and not well understood.

There are many potential reasons why this practice has persisted. Parents often view early marriage as a socially acceptable strategy to protect their daughter against events, like sexual assault or out-of-wedlock pregnancy, that could compromise her purity and subsequent marriageability (see for example World Vision 2013). Grooms also tend to express a preference for younger brides, purportedly due to beliefs that younger women are more fertile, more likely to be sexually inexperienced and easier to control (Field and Ambrus, 2008). Although culture is considered an important driver of the persistence of early marriage, economic conditions may also play a role. Poverty is strongly associated with early marriage worldwide (Harper, Jones, Presler-Marshall, and Walker, 2014). Girls from poor households are almost twice as likely to marry early as compared to girls from wealthier households (Klugman, Hanmer, et al., 2014). In Sub-Saharan Africa and South Asia, this relationship is likely to interact with the widespread tradition of marriage payments. Indeed, the limited empirical evidence available suggests that dowry is increasing in a bride's age, while bride price is at first increasing and then rapidly decreasing in a bride's age, meaning that under both customs, marrying a daughter earlier can be financially more attractive for her parents.[4] Hoogeveen, Van Der Klaauw, and Van Lomwel (2011) hypothesize that bride wealth is a source of insurance against the loss of livestock, but find no empirical relationship between the timing of marriage and rainfall in rural Zimbabwe. In a companion paper, Corno and Voena (2017) show that child marriage responds to income shocks

[3] See UNICEF 2014b.

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

in rural Kagera, Tanzania, where bride price is customary and there is no variation in marriage payment practices. To the best of our knowledge, ours is the first paper to systematically study the relationship between child marriage, economic shocks and marriage payments.

1.2 Marriage payments

Marriage payments, i.e. bride price and dowry, are widespread in developing countries. The prevailing economic view of marriage payments is based on the seminal work by Becker (1991). People enter in the marriage market to find the match that maximizes their expected utility: the market matches partners and determines the division of surplus between them. Given this characterization, marriage payments may emerge as pecuniary transfers to clear the market when the rules for the 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 in the marriage market.[5] Alternatively, different types of marriage payments can emerge in response to scarcity on one side of the marriage market.

There is an important difference between marital customs in sub-Saharan Africa and India: in many Sub-Saharan African countries, bride price is the prevailing norm, while in India, dowry is the most common practice. Traditionally, the practices of bride price was near-ubiquitous across and within Sub-Saharan Africa countries: more than 90% of ethnic groups in Sub-Saharan Africa traditionally paid bride price (Goody, 1976; Murdock, 1967). This practice is not universal in contemporary Africa, but it remains a widespread practice across the region (see Appendix table A1). For example, a household panel survey conducted in Zimbabwe in the mid-1990s revealed near-universality of bride price at the time of marriage; average bride wealth in this data (received primarily in the form of cattle) was estimated to be two to four times a household's gross annual

[5] Traditionally, dowry appears to have served mainly as a pre-mortem bequest made to daughters rather than as a payment used to clear the marriage market (Goody and Tambiah, 1973). However, with development, dowry appears to have taken on a function more akin to a groomprice, a price that brides' parents must pay in order to ensure a husband for their daughter. The transition of the property rights over dowry from the bride to her husband is studied in Anderson and Bidner (2015), who document a similar transition in late-middle ages in Europe. The view of dowry as a pre-mortem bequest to daughters is also at odds with the prevalence of dowry violence in India, whereby grooms threaten domestic violence in order to get higher transfers from their wife's parents (see Bloch and Rao 2002; Sekhri and Storeygard 2013).

income, although partly paid in installments (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 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), where it served primary a pre-mortem bequest function. 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 (Caldwell, Reddy, and Caldwell, 1983; Srinivasan, 2005). 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 by hypergamy and the caste system (Rao, 1993; Anderson, 2003; Sautmann, 2017). Edlund (2006), however, argues that actual net dowries have experienced little change. In the time period of our study, dowry is widespread across India and payments are large in magnitude, often significantly above average household income (Anukriti, Kwon, and Prakash, 2016).

There are several explanations proffered to explain the existence of dowry in India and bride price in Africa. Boserup (1970) offers an hypothesis based on differences in women's agricultural productivity in the two regions. She argues that in Africa, which 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 the direction of marriage payments.[6] In the theoretical framework we present below, we hence follow this hypothesis as the historical source of variation in marriage payment norms across countries.

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

2 The model

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

Below, we present a simpler version of the model with logarithmic utility and a uniform distribution of income heterogeneity. In Appendix B, 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. Overall, we find that child labor, and in particular female child labor, strengthens our main proposition. Second, we extend the model to a more general utility functions and distributions of the heterogeneity.

2.1 Setup

There is a unit mass of households with a daughter and a unit mass of households with a son. There are two periods, which correspond to two life stages for a woman, childhood ($t = 1$) and adulthood ($t = 2$). Note that because men tend to to be older than their wife at marriage, period 1 may correspond to childhood for a woman and typically to young adulthood for a man. The discount factor is denoted by δ.

In each period, household income depends on three components: 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; an idiosyncratic realization ϵ_t which is distributed uniformly on $[0, 1]$; and last the contribution of adult children labor. 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 society is virilocal, and hence upon marriage women move to the groom's family and contribute to its budget. 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 (for example, not experiencing the stigma associated with non-married women), denoted as $\xi^f \geq 0$.

2.2 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, given possible transfers, both parties prefer getting married to remaining single. This implies that the following two conditions are 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 total income is sufficiently low, the bounds on τ_2^* may require a payment to take place, even for the richest families. When historical $w^f > 0$, a bride price payment is necessary to persuade women's parents to let their daughters marry, meaning that

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

Wherever 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 $\tau_2^* \in [\underline{\tau}_2, \bar{\tau}_2]$ that satisfies these conditions. A simple example of equilibrium is one in which 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 $ln(y_2 + \epsilon_2^j + w^m + w^f - \tau_2^*) + \xi^m$ and $ln(y_2 + \epsilon_2^j + \tau_2^*) + \xi^f$. If a couple is already married when entering the second period, the families' payoffs instead are $ln(y_2 + \epsilon_2^j + w^m + w^f) + \xi^m$ and $ln(y_2 + \epsilon_2^i)$.

2.3 Childhood

In the first period, parents decide whether or not to have their children marry.[7] For a given transfer τ_1 paid in marriages that occur in the first period, payoffs are described below.

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:

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

[7] An interesting extension would be to incorporate parental altruism (Doepke and Zilibotti, forthcoming). Here, we model the parents as authoritarian. We discuss below a simple extension that captures parents preferences (or disutility) towards child marriage, which may incorporate the cost that a daughter can face by marrying as a child.

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

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

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 $\Omega^m = \delta E\left[ln(y_2 + \epsilon_2^j + w^m + w^f - \tau_2^*) - ln(y_2 + \epsilon_2^j + w^m + w^f)\right]$. These quantities represent the option value of waiting to marry in the second period. For simplicity, define also $H^f = exp(\Omega^f)$ and $H^m = exp(\Omega^m)$: this definition will become useful below.

2.3.1 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

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

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

$$D^{BP}(y_1, \tau_1) = 1 + y_1 + \frac{\tau_1}{H^m - 1}, \tag{2}$$

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

2.3.2 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

$$S^{DOW}(y_1, \tau_1) = 1 + y_1 - \frac{\tau_1}{H^f - 1} \tag{3}$$

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

$$D^{DOW}(y_1, \tau_1) = -y_1 - \frac{\tau_1}{H^m - 1} \tag{4}$$

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

2.3.3 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 is

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

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

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

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 B. □

Intuitively, our results carry through when the supply curve for brides is flatter (slope $\frac{1}{H^f-1}$ with bride price and $-\frac{1}{H^f-1}$ with dowry) than the demand curve for brides (slope $-\frac{1}{H^m-1}$ with bride price and $\frac{1}{H^m-1}$ with dowry, 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 respond in the opposite way to income shocks in different economies, depending on the direction of the marriage payment, is that women's families are less price sensitive then men's families, who can rely on their adult son's income (and potentially also on their daughter-in-law's income) even after the marriage has occurred.

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

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

Proof. See Appendix B. □

This finding, particularly in the case of Sub-Saharan Africa, is related to 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.

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

Other mechanisms can generate these predictions within this model. For example, interesting dynamics arise if we allow parents to have preferences over the timing of marriage, by introducing a gender-specific cost or benefit of marrying in the first period ξ_1^f and ξ_1^m, which can be positive or negative. These terms affect the slope of the demand and of the supply for brides: to see how they would function, it is sufficient to redefine $H^f = exp(\Omega^f) - \xi_1^f$ and $H^m = exp(\Omega^m) - \xi_1^m$. For instance, if men especially valued marrying younger (more fertile) women, i.e. if $\xi_1^m > 0$, then bride price payments in the first period would be higher and dowry payments would be lower than with $\xi_1^m = 0$. However, in order for these preferences alone to generate opposite responses to shocks for dowry and bride price economies, preferences for child marriage would need to vary systematically across economies as well, which is something that has not been documented in the literature.[8]

3 Data and descriptive statistics

In this section, we describe the sources of data that we exploit to test the main predictions of our model in Sub-Saharan Africa and in India. All datasets used in the analysis are summarized in Appendix table A2.

3.1 Marriage data

Our main data source are the Demographic and Health Surveys (DHS). DHS are nationally-representative, household-level surveys carried out in developing countries around the world. For Sub-Saharan Africa, we assembled all the publicly-available DHS between 1994 and 2013 where geocoded data are available, resulting in a total of 73 surveys across 31 countries.[9] In the DHS, GPS data consist of the geographical coordinates of each DHS cluster (group of villages or urban neighborhoods) in the sample and are crucial for our analysis to identify respondents exposed to local rainfall shocks. The list of African countries and survey waves included in the analysis is reported in the Appendix table A3. For India, we use the DHS collected in 1998 for a direct comparison with the DHS Sub-Saharan Africa sample. In addition, to span a larger time horizon and to exploit useful information about marriage migration, we check that our results are robust to the inclusion of the India Human Development Survey (IHDS) from 2004-05.[10]

[8]For example, assume that the option values is the same for both genders and define it Ω. In order for droughts to increase child marriage in bride price economies, we would need that $\xi_1^f + \xi_1^m < 2\Omega - 2$ (i.e. the joint utility premium for early marriage in Sub-Saharan Africa should be small), while for droughts to decrease child marriage in dowry economies, we need that $\xi_1^f + \xi_1^m > 2\Omega - 2$ (i.e. the joint utility premium for early marriage in India should be large enough).

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

[10]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

Across all the surveys, the information on a 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.[11] The main difference across the surveys is the universe of women that is sampled for the interview. In the Africa DHS, all women in the household between the ages of 15 and 49 are interviewed. In contrast, in the India DHS, all ever-married women aged 15-49 in the household are interviewed.[12] In order to ensure comparability across surveys and avoid excluding never-married women in the sample from Sub-Saharan Africa, we limit our analysis to women who are at least 25 years old at the time of the interview. By this age, most women are married (87% in our African sample). To look at comparable cohorts across the two sets of surveys, we focus on women born between 1950 and 1989.

In the light of the evidence on the correlation between rainfall and conflicts (Miguel, Satyanath, and Sergenti, 2004) and between civil conflict and marriage (Jayaraman, Gebreselassie, and Chandrasekhar, 2009; La Mattina, 2017), we expect that marriage markets will be significantly affected by the intensity of civil conflicts in Sub-Saharan Africa. For this reasons, we exclude women exposed to major civil conflicts between ages 12 and 17. To identify the onset and end of the main conflicts in Sub-Saharan Africa in our sample period, we use data from UCDP/PRIO Armed Conflict Dataset, as detailed in Appendix table A4.

As reported in table 1 Panel A, our final sample consists of 326,645 women in Sub-Saharan Africa, and 66,466 women in India. Figure 2 plots the distribution of ages of marriage in our data. We consider women who marry from age 12 onwards. Indeed, only few marriages are recorded before the age of 12 years. In both regions, the hazard into early marriage is relatively low up until age 13 or 14, which is consistent with the hypothesis that girls are often considered ready for marriage at the onset of puberty, that usually occurs sometime in the early teenage years (Field and Ambrus, 2008). The mean age at first marriage is low, 18.7 years in Africa and

provide information on women's district of residence: this is why we complement our Indian data with the IHDS instead. The IHDS is a nationally-representative, household-level survey first carried out in 2004-05. A second wave was held in 2011-12, but it features primarily panel information on the married women who were already interviewed in the previous wave, and hence does not add a significant number of observations to the 2005 sample. The two Indian surveys do not contain GPS coordinate information; instead, they provide information on each woman's district of residence, which we can use to match each observation to the history of weather shocks.

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

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

17.6 years in India, and a significant fraction of women are marrying before age 18 (46.7% and 53.9% in Africa and India, respectively).

3.2 Weather data and construction of weather shocks

To examine how income shocks affect the early marriage hazard for young women, we follow an approach that is widely used in the economics literature, exploiting variation in local rainfall as a proxy for local economic conditions (see Jayachandran (2006); Burke, Gong, and Jones (2015); Kaur (2014); Shah and Steinberg (2016) among many others). The appeal of this approach is that rainfall is an exogenous event that has meaningful effects on economic productivity in both Africa and India, where rural households rely heavily on rain-fed agriculture for their economic livelihood. Droughts, in particular, tend to suppress agricultural output, which has deleterious effects on households' incomes.

To construct a measure of local droughts, we use rainfall data produced by geographers at the University of Delaware ("UDel data"). The UDel dataset provides estimates of monthly precipitation on a 0.5 x 0.5 degree grid covering terrestrial areas across the globe, for the 1900-2010 period.[13] For Africa, we use the GPS information in the DHS data to match each DHS cluster to the weather grid cell and calculate rainfall shocks at the grid cell level. Our main sample matches up to 3,180 unique grid cells across 31 countries in the Sub-Saharan African region, each of which is approximately 2,500 square 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, 440 in 26 states are represented in our main sample, and these districts have a mean area of over 5,000 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 (2015) and define a drought as calendar year rainfall below the 15th percentile of a location's (grid cell or district) long-run rainfall distribution. We use a long-run time series (1950-2010) of

[13] 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 2015). For a detailed overview of the UDel data and other global weather data sets, see Dell, Jones, and Olken 2013.

rainfall observations to fit a gamma distribution of calendar year rainfall for each location. We then use the estimated gamma distribution for a particular location to assign each calendar year rainfall realization to its corresponding percentile in the distribution. We also explore robustness to a rich set of alternative definitions of rainfall shocks.

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

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

3.3 Weather shocks and crop yields

The relationship between weather shocks and agricultural output is well established in the literature. In this subsection, we explore how the specific measure of rainfall shocks we constructed affects aggregate crop yields in Sub-Saharan Africa and India. To do so, we combine the rainfall data with yield data, which are available annually for each country in Sub-Saharan Africa over the period 1960-2010 from the FAOStat and for India over the 1957-1987 period from the World Bank India Agriculture and Climate Data Set.

For Sub-Saharan Africa, we estimate the impact of drought on the natural logarithm of yields of the five main staple crops growing in the continent: maize, sorghum, millet, rice, and wheat.

Since we only have country-level yield data, we construct measures of country-level droughts in the same manner as in the main analysis. All the estimates include year and country fixed effects, so the impact of drought on agricultural output is identified from between-countries and between-years variation in rainfall. As shown in table 2, droughts (rainfall below the 15th percentile) reduce maize, rice, wheat, sorghum and millet yields looking both at the set of Sub-Saharan African countries available in the FAO database (columns 1-6) and at the 31 countries part of our DHS sample (columns 7-12). In particular, droughts reduce average cereals yields by 12 percent (columns 6 and 12, $p < 0.01$).

Similarly, for India, we rely on crop yield data from the World Bank, which has the great advantage of providing crop yields at the district level. We look at the impact of rainfall shocks (constructed at the district-level) on the natural logarithm of the yields of five most important crops in the country (rice, wheat, jowar, maize and bajra). As reported in table 3, droughts negatively and strongly affects yields of all the major crops cultivated in India. On average, drought reduces average crop yields by 16% (column 6, $p < 0.01$).

These findings are further supported by the evidence provided in Appendix figures A2 and A3, 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 shocks and yields across the distribution of rainfall realizations. In Sub-Saharan Africa, lower rainfall is clearly associated with lower agricultural output, but it is harder to identify a clear positive relationship between higher rainfall realization and crop yields, at least with the type of geographical variation that we are exploiting (figure A2). Similar patterns are found for crop yields in India, where we document a consistently positive correlation between rainfall and yields for low levels of rain, and a less clear one for higher levels (figure A3). The notable exception is rice, for which a higher level of rainfall realization is positively associated with output (panel b).

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

4 Empirical strategy

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

4.1 Main specification

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

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

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 Sub-Saharan Africa, district in India) born in cohort k and entering her first marriage at age t as follows

$$M_{i,g,k,t} = X_{g,k,t}\beta + \alpha_t + \omega_g + \gamma_k + \epsilon_{i,g,k,t}. \quad (5)$$

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, we examine data on women till age 24 or 17, depending on the specification. Thus, women married after age 24, or 17, are right censored.[14] The variable $X_{g,k,t}$ is a time-varying measure of weather conditions in location g during the year in which the woman born in year k is age t. Specifically, included

[14] For example, a woman who is married at age 16 would appear five times in the regression for child marriage, and her marriage vector would be $\{M_{i,k,12}, ..., M_{i,k,15}, M_{i,k,16}\} = \{0, ..., 0, 1\}$. A woman who is not married by age 17 appears in the data six times, and her marriage vector is a string of zeroes.

in $X_{g,k,t}$ are a dummy indicator for a drought in a given year. β are the main coefficients of interest and measure the effect of rainfall shocks on the probability of marriage. α_t is a vector of age fixed effects, which controls for the fact that marriage has a different probability to occur at different ages. We include location-specific fixed effects, ω_g, to control for time-invariant local unobservable characteristics, such as geographic, economic and cultural factors, and year-of-birth fixed effects γ_k to account for cohort effects. Since we are combining data across multiple countries, we use population-weighted survey weights to make the results representative of the countries included in the analysis. We estimate regressions with standard errors clustered at the grid-cell (for Sub-Saharan Africa) or district (for India) level, to allow for serial correlation in the error terms across women in the same area, and show robustness to clustering at larger geographic units.

With the inclusion of location (grid cell or district) and year of birth fixed effects, the impact of weather shocks on the 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. 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 the marital timing decisions (Vogl, 2013).

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

4.2 Cross-sectional regressions

To study the characteristics of couples that form during droughts, we examine the following specifications, for household i living in location g (grid cell in Sub-Saharan Africa, district in India) born in cohort k and married in year τ:

$$y_{i,g,k,\tau} = X_{g,k,\tau}\beta + \delta_\tau + \omega_g + \gamma_k + \zeta_i + \epsilon_{i,g,k,\tau}. \quad (6)$$

In this specification, $X_{g,k,\tau}$ are time-varying measures of weather conditions (i.e. droughts) in location g during the year in which the woman marries τ. We control for location fixed effects ω_g, for current age (at the time of the survey) fixed effects ζ_i, for year of birth γ_k, and for year of marriage δ_τ. It is important to notice that we cannot assign any causal interpretation to these estimates, as they are the result of both selection forces (i.e. the characteristics of individuals who chose to marry during a drought may differ from those who didn't) and causal forces (i.e. the fact that a couple married during a drought may lead to different long-term outcomes).[15]

4.3 Long-run effects of droughts

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

$$y_{i,g,k} = X_{g,k,t}\beta + Z_{i,g}\delta + \omega_g + \gamma_k + \zeta_i + \epsilon_{i,g,k,t}. \quad (7)$$

In this specification, y represents two outcome variables: the age of marriage and the total number of children, while X is a vector containing the number of droughts that woman i has experienced over different age ranges: 12-14, 15-17,18-20, 21-24. In addition to location and year-of-birth fixed effect, we control for country fixed effects and for current age also in Sub-Saharan Africa.

4.4 Threats to identification

A potential threat to our identification strategy comes from the fact that we are considering weather shocks in the respondent's location at the time of the survey rather than at the time of marriage. Unfortunately, the DHS (and the IHDS) elicit information on where a women currently resides, but not on where she resided around the time of her first marriage. This data

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

limitation may introduce error in our measure of rainfall shocks if the respondent's recorded place of residence is different, and sufficiently far, from her location at the time of marriage. This can happen for two main reasons. The first one relates to the custom of virilocality. In India and in many parts of Africa, a daughter joins the household of the groom and his family at the time of marriage. Thus, the village they live in at the time of the survey may differ from the one where they grew up in. In their seminal paper on marriage migration (Rosenzweig and Stark, 1989) argue that marrying a daughter to a man in a distant village reduces the co-movement of parental household income and daughter's household income, which facilitates the possibility of making inter-household transfers in times of need.[16] The second reason is due to the possibility that the respondent and her families may simply migrate after marriage but before the survey takes place.

While virilocality is common in both regions, the available data on marriage migration indicates that most married women do not move far from their natal home. Table A5 in the Appendix reports migration pattern for the set of African countries in our analysis and for India. Panel A, column 1, shows that more than 77% of women do not move at the time of marriage in Sub-Saharan Africa. Furthermore, when migration does occur, previous literature suggests that it happens across relatively short distances. Mbaye and Wagner (2013) collect data in Senegal and find that married women live an average of 20 kilometers from their natal home. Unfortunately, information on the distance from natal home to the current location is not available in the DHS.

In India, marriage migration is more common: 58.02% of women migrated at the time of marriage. Again, though, migration happens at a relative close distance or likely within the geographic area at which we define our rainfall shocks. By exploiting information in the IHDS, we found that the median travel time between a married woman's current residence and her natal home is 2 hours at the median and less than 6 hours for 90% of the respondents (see table A5, panel B). To better understand migration patterns in India, we also look at empirical evidence coming from previous literature. In Rosenzweig and Stark (1989)'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-

[16]This explanation has questioned in a recent work by Fulford (2013), who shows that inter-household transfers from daughters to parents are virtually non-existent in India, and that households in areas with high rainfall volatility do not send daughters to more distant villages, as might be expected under the theory.

88 Indian National Sample Surveys (NSS), only 6.1% of households are classified as "migrant households", those for which the enumeration village differs from the respondent's last usual residence. Furthermore, only a small percentage of women move after marriage and even if they migrate, they do not move very far away.

While marriage migration over vast geographic areas does not appear to be a major threat in our contexts, another potential concern for our identification strategy is whether marriage migration may happen differentially during a drought. For example, if women who are getting married are more likely to migrate to an area exposed to a drought, we would expect a positive correlation between marriage probability and droughts. On the contrary, if women are less likely to migrate to a drought area at marriage, we would expect a negative correlation between marriage probability and droughts to arise spuriously. To examine whether either of these scenarios is likely to occur, we estimate the relationship between the occurrence of a drought at the time of marriage and a set of marriage migrations outcomes from the DHS and the IHDS. In Sub-Saharan Africa, women do not appear less likely to have remained in their village of birth (table A6, column 1), nor to have migrated for marriage during a drought (column 2). In India, we do not find that drought affect marriage migration, nor distance from the village of origin (table A6, columns 3-5).

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

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

5 Main results

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

5.1 Effect of rainfall shocks on the timing of marriage

Table 4 reports our first set of results: the effect of adverse rainfall shocks on the timing of marriage for young women aged 12 to 24. We report the estimated coefficients for equation 5 separately for the Sub-Saharan African countries in our sample (columns 1-3) and for India (columns 4-5). All specifications for the Sub-Saharan Africa sample include grid cell fixed effects and those for India include district fixed effects. Consistently with our theoretical model, we find that adverse rainfall shocks have opposite effects on the timing of marriage in the two regions: in Sub-Saharan Africa, droughts increase the probability of early marriage while in India droughts decrease it. In Africa, women who experience a drought between ages 12 and 24 are 0.37 percentage points (pp) more likely to get married in the same year (columns 1-2, $p < 0.01$). The average annual marriage hazard for this age group is equal to 0.113, and hence the effect corresponds approximately to a 3.3% increase. Even after controlling for fixed effects for each country-by-cohort of birth combination, we find that the effect of a drought is equal to 3.2 percentage points (column 3, $p < 0.01$).[17] In line with the predictions of our model, income shocks have an opposite effect among Indian women. In India, women who experience a drought between ages 12 and 24 are 0.41pp *less* likely to get married in a given year (column 4, $p < 0.01$). Given a mean of the dependent variable of 0.145, this effect corresponds approximately to a 2.8% decline. Including fixed effects for the interaction between states dummies and cohort dummies further decreases the coefficient to -0.44pp (column 5, $p < 0.01$).

In figure 4, we explore the heterogeneity of this effect by the woman's age by interacting drought with each age dummy. Consistently with our model, the effects are concentrated in early years, and particularly among child marriages (before the age of 18) in both countries. In Sub-Saharan Africa, the strongest effects are observed between ages 15 and 18 and at age 21, with no effects at later ages (panel a). In India, the effects are concentrated between ages 14 and 16 only (panel b).

Hence, in table 5 we focus on child marriage, our main outcome variable. We restrict the panel dimension of our dataset between age 12 and 17, and find that, similarly to what reported above, droughts have opposite effects on the hazard into marriage at these early ages in the two regions. In Sub-Saharan Africa, girls who experience a drought between ages 12 and 17 are 0.2-0.26pp more likely to get married in the same year (columns 1-2, $p < 0.05$ and column

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

3, $p < 0.10$). The average annual marriage hazard for this age group is equal to 0.088, and hence the effect corresponds to a 2.3%-3% increase in the annual hazard of child marriage. In India, women who experience a drought between ages 12 and 17 are 0.46-0.47pp less likely to get married in that same year (columns 4-5, $p < 0.01$). Given a mean of the dependent variable of 0.109, this effect corresponds to a 4.2-4.3% decline in the annual hazard of child marriage.

In subsection 6.3, we extensively analyze the robustness of these findings to alternative specifications of the sample and of the main independent variable.

5.2 Heterogeneity of the effects between and within countries

Why does a negative rainfall shock, which affect agricultural output in the same way in Sub-Saharan Africa and India, have an opposite effect on the timing of marriage and most importantly on the harmful practice of child marriages? As illustrated in our theoretical model, the traditional marriage payments that prevail in the two regions can generate incentives for parents to time their children's marriage as a consumption smoothing mechanism. In this section, we examine whether the direction and the intensity of marriage payment norms can account for the heterogeneity in the effects of droughts between and within the countries in our sample.

5.2.1 Effects by marriage payment norm in Sub-Saharan Africa

We first exploit historical heterogeneity in marriage payments across ethnic groups in different countries within Sub-Saharan Africa. Our data source for measuring traditional marriage customs in different ethnic groups is George Peter Murdock's (1967) *Ethnographic Atlas*. The Atlas provides historical information on transfers made at marriage, either bride price or dowry, by ethnic groups and has been extensively used in the literature, often in combination with the DHS (see Alesina, Giuliano, and Nunn 2013, Alesina, Brioschi, and La Ferrara 2016 and Michalopoulos, Putterman, and Weil 2016 among others). For each ethnic group, the Atlas provides information about the *mode of marriage* (variable v6 in the database), which is the traditional marriage payment norm. We use the information from the *Ethnomaps* on the size of each ethnic group in a given country to construct a measure of prevalence of the bride price norm within each country in our sample, as reported in Appendix Table A1.[18] Countries with a share of the population belonging to ethnic groups with a bride price prevalence equal or greater than

[18] *Ethnomaps* are available at http://www.ethnomaps.ch/hpm-e/atlas-e.html, accessed February 7, 2016.

50% include all Sub-Saharan Africa countries except Eritrea, Madagascar, Malawi, Mozambique and Zambia. Figure 3 clearly shows across-countries variation in marriage payments custom in the countries in our sample.

By using historical information on marriage payments at the country level, rather than actual payments, we circumvent a fundamental empirical challenge. First of all, information on actual bride price payments is unfortunately not available in the DHS nor in any cross-country source of data for Sub-Saharan Africa. Second, bride price payments are endogenous to the economic circumstances at the time of marriage, as shown in our model. We follow Ashraf, Bau, Nunn, and Voena (2016), who use data from Zambia and Indonesia to show that bride price payments are substantially higher among ethnic groups that traditionally engage in bride price payments according to the *Ethnographic Atlas*.

In table 6, we report the estimated effects of rainfall shocks in Sub-Saharan Africa exploiting heterogeneity in bride price prevalence across countries. Columns 1 and 2 show the effect of drought on child marriage for the subsample of Sub-Saharan Africa countries where the bride price custom is the prevailing norm (BP$\geq$ 50%). Descriptive statistics or this sample are reported in table 1 Panel B. We find that droughts have a strong effect on the early marriage hazard: during a drought, the annual hazard into child marriage increases by 0.26pp or 3% (columns 1-2, $p < 0.05$). On the contrary, no statistically significant association between adverse rainfall shocks and child marriage emerge in countries with a bride price prevalence lower than 50% (columns 3-4). Hence, in areas where bride price is the prevalent mode of payment at the time of marriage, households hit by negative income shocks and with little access to credit market encourage their daughters to marry before they reach adulthood to obtain the bride price payment at a time when the marginal utility of consumption is the highest. More interestingly, on average there does not appear to be a relationship between aggregate income fluctuations and the timing of marriage in countries where marriage payments are not among the majority of the population.

To dig deeper into the role played by marriage payments in shaping early marriage's decision, we next test our main effect in Eritrea. According to the *Ethnographic Atlas* and the *Ethnomaps*, the Tigrigna people of central Eritrea – the largest ethnic group in the country, originating from Egypt – is the only ethnic group to engage in dowry payments within Sub-Saharan Africa. Several sources report that dowry is now widespread throughout the country, even though multiple norms coexist (Tronvoll, 1998; Gebremedhin, 2002; Favali and Pateman, 2003; Tesfagiorgis, 2010). Hence, we next study the effect of droughts using data from the 2002 Eritrea DHS.[19] According to our model, we should observe a negative relationship between droughts and early marriages in countries where young girls' families have to pay a dowry at marriage: when adverse shocks occur, parents would prefer to wait to marry their daughter. The results reported in column 5 of table 6 confirm this hypothesis: when focusing on Eritrea only, we find that droughts reduce the hazard of child marriage in the same year by 1.2pp (a 14% reduction, $p < 0.10$). This finding further indicates that marriage payments indeed are likely to play a role in marriage's decisions: even within Africa, in the presence of an income shock and in places where dowry is the prevailing mode of payment at marriage, a young girl is less likely to get married when a drought occurs.

To further corroborate our theory, we explore the relationship between traditional marriage payments and the impact of drought on child marriage by exploiting heterogeneity in marriage payments customs within Sub-Saharan Africa countries, taking advantage of the comprehensive concordance of the ethnic groups reported in the DHS to those featured in the *Ethnographic Atlas* compiled by Alesina, Brioschi, and La Ferrara (2016). Out of the five countries where less than 50% of the population engages in bride price payments (see table A1), Alesina, Brioschi, and La Ferrara (2016) features a concordance for three countries: Malawi, Mozambique and Zambia. We restrict our within-country analysis to Malawi and Zambia because the extensive civil conflict in Mozambique substantially limits the sample size from this country (see table A4). In Zambia, as documented with unique survey data on bride price payments from Lusaka collected by Ashraf, Bau, Nunn, and Voena (2016), ethnic groups that historically engage in bride price payments make significantly larger bride price payments today, while other groups, which are often classified as making so-called "token" bride price payments in the *Ethnographic Atlas*, make lower bride price payments today. Hence, at least for Zambia, we know that historical norms related to bride price have predictive power for current behavior. No microeconomic data on bride price payments is available for Malawi, to the best of our knowledge. In Appendix table A7, we report the coefficients that we obtain for estimating equation 5 separately for Malawi (columns 1-3) and for Zambia (columns 4-6). Of course, the power of his exercise is limited by the small number of observations in each subsample: 17,140 women in Malawi and 11,913 in Zambia. While no effects of droughts on child marriage can be detected in Malawi, we find that

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

in Zambia, girls from ethnic groups that traditionally engage in bride price payments are 0.94pp more likely to marry when a drought occurs between ages 12 and 17 (column 6). Compared to a mean of the dependent variable of 0.084, this effect corresponds to approximately a 12% increase (column 6, $p < 0.10$).

5.2.2 Heterogenous effects within India

In contemporary India, dowry payments are widespread across all regions, castes and ethnic groups (Anukriti, Kwon, and Prakash, 2016). Yet, the literature extensively documents and reports that they originated in the Hindu community (Goody and Tambiah, 1973), among which the tradition remains stronger (Borooah and Iyer, 2004; Bloch, Rao, and Desai, 2004; Srinivasan, 2005). We therefore investigate the effect of rainfall shocks on the hazard into early marriage, exploiting heterogeneity across religious groups, and focusing on Hindus and Muslims, who constitute 75% and 11% of our sample respectively, compared to all other religious groups (Christians 7%, Sikhs 3% and other smaller groups).

In table 7, we augmented equation 5 with the interaction between drought and a dummy variable equal to 1 if women i reported Hinduism as main religion and 0 otherwise in the DHS (Hindu), a dummy variable equal to 1 if women i reported Islam as main religion and 0 otherwise in the DHS (Muslim) and the interaction between drought and a dummy variable indicating that the respondent belong to another religious group (Others). We also interact birth year and age fixed effects with the full set of religion dummies. Column 1 shows that the coefficients on *Drought* × *Hindu* is equal to -0.53pp ($p < 0.01$), while the one on Muslims is close to zero, suggesting that the effect of negative rainfall shock on early marriages is concentrated among groups where dowry payment is a deeply rooted cultural norm. These findings are robust to the inclusion of the interaction between state fixed effects and cohort fixed effects, although the difference between the coefficients becomes attenuated in this specification (column 2).

Overall the results in tables 6, A7 and 7 suggest that norms on marriage payments in different contexts can generate an opposite effect of how an economic shock affects households' decisions on child marriage, while there does not appear to be any effect of droughts on child marriage where marriage payments are not customary.

6 Additional results and robustness checks

In this section, we first study the effects of rainfall shocks on the timing of fertility and on the number of children. We then investigate the characteristics of the matches that form during droughts. Lastly, we examine the robustness of our main findings to a wide array of specification tests.

6.1 Effects of rainfall shocks on fertility

A dramatic consequence of child marriage is early fertility, which is arguably one of the most important risks facing teenage girls in developing countries, especially in Sub-Saharan Africa (Duflo, Dupas, and Kremer, 2015). In addition to its socioeconomic consequences, pregnancy in adolescence is associated with increased risks of maternal and fetal complications, including premature delivery (Kirbas, Gulerman, and Daglar, 2016), and with worse health and socioeconomic outcomes for the next generation (Fergusson and Woodward, 1999; Chari, Heath, Maertens, and Fatima, 2017). In our sample from Sub-Saharan Africa and India, 32% and 31.5% of women respectively have their first child before turning 18.

Documenting an effect of weather shocks on the timing of fertility is also important to show that our main findings are likely to have long-term consequences on women's lives, and possibly on those of their children. Hence, in what follows, we study both the effect of droughts on the onset of fertility, substituting marriage with birth as the outcome variable in equation 5, and the effect of droughts on overall fertility, measuring at impact of the cumulative number of droughts experienced by a woman in her youth on her parity as in equation 7. Of course, age of marriage is only one of the many channels through which an income shock can affect fertility. For example, women may choose to time fertility to avoid lean seasons or, on the contrary, to take advantage of times when the marginal product of their labor is lower (Pitt and Sigle, 1998). Yet, the differential patterns we document across countries within Sub-Saharan Africa are consistent with the hypothesis that changes the timing of marriage may generate a shift in the timing of first birth and, particularly in Sub-Saharan Africa, in overall fertility rates.

6.1.1 Effects on the timing of the first birth

We begin by examining the effect of negative rainfall shocks on the annual hazard of having a child before the age of 18, by replacing the marriage outcome variable with a variable that takes value 1 when a woman has her first child. We find that in Sub-Saharan Africa a drought increases the annual hazard of early fertility by 0.22-0.18 percentage points (table 8, columns 1-3, $p < 0.05$), which corresponds to a 4-3.5% increase relative to a mean dependent variable of 0.055. We find no effects of rainfall shocks on the timing of fertility in India.

In Appendix table A8, we examine these effects extending the age range up to age 24. In this sample, the effect of drought on the timing of first fertility ranges from 0.34 to 0.30pp in Sub-Saharan Africa (columns 1-3, $p < 0.01$).

6.1.2 Long run effects on fertility

Having documented the effect of droughts on the timing of marriage and fertility, we now turn to investigate their long-term effects, estimating equation 7 over different samples. We first examine the sample of countries within Sub-Saharan Africa that have at least 50% of the population traditionally engaging in bride price payments. We find that an additional drought in a given year between ages 12 and 24 reduces the age of marriage by 0.04-0.05 years (table 9 column 1, $p < 0.05$ for ages 15-17 and 20-24). At the same time, an additional drought increases the number of children that a woman has at the time of the survey by 0.04 (column 2, $p < 0.05$ for ages 12-14 and 20-24 and $p < 0.01$ for ages 15-17 and 18-20), out of a mean of 4.4 children per woman in the cross-section. While the timing of marriage is a likely important channel of this shift in fertility behavior, other factors, such as changes in education and human capital, should also play a role, in particular in the earlier ages.

We next focus on the subsample of countries in which bride price is not the prevailing norm (Madagascar, Malawi, Mozambique, Zambia and Eritrea). In these countries, we find that droughts have no effect on the age of marriage (column 3). Moreover, most likely because of an income effect, women from these countries respond in an opposite way to what we encountered above: experiencing droughts reduces the number of children a woman ends up having by 0.05-0.08 (column 4, $p < 0.10$ for ages 12-14, $p < 0.01$ for ages 15-17 and 18-20, and $p < 0.05$ for ages 20-24).

Last, we find that in India, droughts increase the age of marriage, particularly when experienced during the late teenage year, as seen in figure 4. Experiencing an additional drought between ages 15 and 17 increases age of marriage by 0.05 years (column 5, $p < 0.10$), but appears to have no effect at later ages. Fertility also appears to vary according to the history of droughts experienced by a woman, consistently with an income effects and possibly a marriage effect. Drought effects get stronger with age: experiencing an additional drought between ages 20 and 24 reduces the number of children a woman ends up having by 0.05 (column 6, $p < 0.05$), while effects at other ages are smaller and not statistically significant.

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

Who matches during a drought? To examine the characteristics of marriages that form during years of drought and flood, we estimate equation 6 on a set of characteristics of the household. In Sub-Saharan Africa, we find that the women who marry during droughts are 1.2 percentage points more likely to be uneducated (table 10, column 1, $p < 0.05$), and they tend to marry men of similar education and age as those who marry during regular times (columns 2-3). They are not more likely to be in polygynous marriages, but may be slightly more likely to be a first wife in a polygynous union, possibly because of the earlier marriage (columns 4 and 5). Finally, they are 0.05 percentage points more likely to have no say in household 's decisions (column 6, $p < 0.05$).[20]

In the data from India, we find no significant differential patterns among the couples that form during droughts and those who don't (columns 7-10), possibly because of the smaller sample size or because matches are often established well in advance of the marriage. An additional analysis shows that lack of power is the most plausible explanation: when we combine data from the 1998 DHS with data from the 2005 IHDS, we find opposite patterns compared to those documented for Sub-Saharan Africa. In particular, women who marry during droughts are 1.6pp less likely to be uneducated (Appendix table A9, column 1, $p < 0.10$) and are 1.2 less likely to have "no say" in household's decisions (column 4, $p < 0.10$).

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

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

6.3 Robustness checks

In this subsection, we perform a wide array of robustness checks and additional tests on our data.

6.3.1 Robustness to alternative definitions of rainfall shocks

As a first robustness check to our main results, we study how the impact of drought varies with the definition of our drought measure. We use three approaches. First, we re-estimate our main regression equation varying cutoff levels to define a drought, ranging from the 5th percentile to the 45th percentile. Figure 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 the definition of drought becomes more severe, the estimated impact increases in absolute value.

Second, in table A10 we examine the association between the level of rainfall and the hazard into child marriage, following our usual specification. We find that an increase in annual rain by 1 meter is associated with a decline in the child marriage hazard by 0.46-0.35 percentage points in Sub-Saharan Africa (columns 1-2, $p < 0.05$, not significant at conventional levels in column 3), and with an increase in such a hazard by 0.39-0.41pp in India (columns 4-5, $p < 0.10$).

We know from figures A2 and A3 that high level of rain have ambiguous effects on agricultural output, particularly for rice. To further investigate the relationship between high level of rainfall and child marriage, we add to our main specification a variable that captures floods, defined as rainfall realizations that exceed the 85th percentile of rain. We find that floods have no discernible effect on the child marriage hazard in Sub-Saharan Africa (Appendix table A11, columns 1 and 2) but reduce the child marriage hazard in the India DHS sample (column 3, $p < 0.01$). As expected, though, the negative effect of floods is concentrated in regions that do not cultivate rice: when the percentage of land cultivated as rice is added to the regression and interacted with flood, the interaction has a positive sign which exceeds the absolute value of the main effect of flood (column 4, $p < 0.05$).

Third, we estimate our main regression equation with indicators for the bottom rainfall quintiles between 1950 and 2010. Effects are comparable to our measure of drought in India, but weaker in Sub-Saharan Africa, as expected given that effects fade out substantially after the 15th percentile in figure 5 (see Appendix table A12, column 1 $p < 0.10$ and column 2 $p < 0.01$).

Last, we consider the time structure of the effect of droughts, by examining lagged and future shocks. In our model, without credit markets and with no serial correlation in the shocks, only contemporaneous droughts affect behavior. When households can save or when shocks are correlated over time, one may expect past shocks to matter for the current child marriage hazard as well. Indeed, when we examine Sub-Saharan Africa, we find that past and future shocks have no effect on the marriage hazard (Appendix table A13, columns 1-3). In India, past shocks have a smaller but sizable effect on the marriage hazard relative to contemporaneous shocks, while future shock does not appear to matter, reassuringly (columns 4-6).[21]

6.3.2 Inference: clustering at larger geographic units

To account for the potential correlation in error terms across space between different grid cells in Sub-Saharan Africa and districts in India, we consider clustering our standard errors at the country level and at the state level respectively. To account for the small number of Indian states in our sample, we also compute wild bootstrapped p-values following Cameron, Gelbach, and Miller (2008). In table A17, we replicate the estimates from table 5 and report the corresponding p-values under the different clustering assumptions. We observe only small changes in p-values after the clustering at much larger geographic units, which do not affect the statistical significance of our estimates.

6.3.3 Specification checks for the Sub-Saharan African sample

As an additional robustness check, we verify that our Sub-Saharan Africa findings persist when we do not use population-weighted sampling weights (table A14 column 1, $p < 0.05$), when we use the most recent wave of data for each country (column 2, $p < 0.05$) and when we focus on the subsample of ever-married women, which is more directly comparable to the India DHS (column 3, $p < 0.05$).

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

6.3.4 Robustness checks for the Indian sample

To study whether our findings continue to appear in later datasets from India, which span a time period closer to that of the DHS from Sub-Saharan Africa, we examine the impact of droughts in the 2004-2005 IHDS. In the IHDS data, droughts reduce the child marriage hazard by 0.85 percentage points (Appendix table A15 columns 3 and 4, $p < 0.01$). When we pool together the DHS and the IHDS, adjusting sampling weights for population, we find that droughts reduce the child marriage hazard by 0.97-1pp (columns 5 and 6, $p < 0.01$).

As additional robustness check, we explore the heterogeneity in the effect of droughts by local conditions across Indian states. First, we examine heterogeneity by the availability of irrigation, using data from the ICRISAT District Level Database of 19 States of India between 1996 and 2011. We construct a dummy variable named *High Irrigation* for states which in a given year are in the top quartile of irrigation, defined as the percentage of cultivated land which is irrigated. Other states are defined as being *Low Irrigation*. Effects appear to be concentrated in states that have low irrigation, and the p-value of the Wald test for equality between *Drought* × *Low Irrigation* and *Drought* × *High Irrigation* is $p = 0.0598$ (Appendix table A16, column 1). Of course, irrigation is correlated with many other measures of local development that can also attenuate the effect of drought. One example is the development of the local banking sector, which varies substantially over time and across space in India (Burgess, Pande, and Wong, 2005). We follow Jayachandran (2006) and use the three measures in that article: the number of bank branches per 1000 people between 1960 and 1999, the number of per-capita bank deposits in 1981 and the number of per-capita bank credits in 1981. For each measure separately, we define a state as having *High Banking* equal to 1 if it is in the top quartile of each variable in each year: for the first measure, this is a time-varying variable, and for the remaining two it is stable over time. For all three variables, we find that the effect of droughts are only statistically significant in states that have low development of the banking sector, while no statistically significant effect can be found in the *High Banking* states. However, we cannot rule out that the effects are the same from a statistical viewpoint (columns 2-4, the p-values of the Wald test for equality of the coefficients are $p = 0.3371$, $p = 0.3622$ and $p = 0.3485$).

7 Mechanisms: additional evidence from India and Indonesia

A key implication of our theoretical model is that marriages that occurred during droughts should command lower payments. The decline in the marriage payments, combined with the different price sensitivities of the two sides of the market, generates our equilibrium result on the probability of child marriage. Studying this implication of the model is not possible with the DHS or the IHDS, because neither survey features data on actual marriage payments. More generally, for bride price, no nationally representative dataset from Sub-Saharan Africa is available, to the best of our knowledge.[22] We hence turn to a new dataset for India and to a new context (Indonesia) for bride price.

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

For bride price, we turn to Indonesia, a country in Southeast Asia with an ancient bride price tradition, as documented in Ashraf, Bau, Nunn, and Voena (2016). Rich data from the Indonesia Family Life Survey (IFLS) provides information not only on the location of current residence, but also on the location at birth and on migration history. Most importantly, it also collects information on bride price payments that were made for each couple's marriage. We use the 2000 (3rd round) and the 2007 (4th round) waves of the survey. We focus on the province of birth of each female respondent, and merge rainfall data from UDel aggregated at the province level. There are 18 provinces of birth in our sample.

Both the REDS and the IFLS samples are rather small: for the groups we use in the rest of the analysis, we have 5,513 women in the REDS and 11,745 women in the IFLS. Indeed, we find no significant effects of droughts on the timing on marriage in either of the two samples. However, our model predicts that marriage payments for all child marriages should be lower during droughts, and not only for the marginal marriages. This implication suggests that we

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

may be able to detect effects on marriage payments in relatively small samples. Hence, we move to estimating equation 6 on the REDS and IFLS samples, using the natural logarithm of the marriage payment for child marriages as the dependent variable.

In the REDS data, the mean dowry for the sample of 2,169 child marriages is equal to 80,132 INR, with a standard deviation of 118,223.[23] There is a negative association between dowry paid and marriages occurred during droughts, which are around 17% lower than baseline (table 11, column 1 $p < 0.10$). This finding is indeed highly consistent with proposition 2. However, it is worth emphasizing that such a finding may also be due to a differential selection of women into marriage during droughts. Adding controls for the brides' age of marriage (column 2) and education (column 3) does not substantially change our estimates, suggesting that selection on observables is unlikely to be driving this result.

In the IFLS, the mean dowry for the sample of 1,131 child marriages is equal to 692,544 Indonesian rupees (in real 2005 values), with a standard deviation of 1,589,108. Dowries are 45 percent lower when a drought hits a woman's province of birth. The coefficient is almost unchanged when we include additional controls for the woman's characteristics (table 11, column 4-6, wild-bootstrapped p-values clustered at the province level $p = 0.108$, $p = 0.104$ and $p = 0.092$ respectively).

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

8 Conclusions

This paper studies the relationship between aggregate economic conditions and the timing of marriage, and in particular the hazard into female child marriage, when markets are incomplete and marriage payments are prevalent. We develop a simple equilibrium model showing that temporary income shocks can affect child marriage in equilibrium and that cultural norms on marriage payments determine the sign of the effect. Consistently with our model, we then find that negative rainfall shocks have opposite effects on the hazard into child marriage in Sub-Saharan Africa and India, while having similar effects on agricultural output in the two regions. In those Sub-Saharan African countries, where bride price payments are customary, droughts

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

lead to an increase in the early marriage hazard, while in India, where dowry is pervasive, droughts lead to a decrease in the early marriage hazard. These effects, particularly in Africa, are associated with changes in the timing of fertility and in overall fertility rates. In line with our theoretical framework, we also find that both dowry and bride price payments drop during droughts, indicating that general equilibrium effects are important in explaining these effects.

Our findings indicate that in developing countries where marriage payments are customary, the age of marriage responds to short-term changes in aggregate economic conditions in a way that is consistent with simple economic theory. This suggests that there is a potential for economic policy to influence marriage markets, however in complex ways that interact with traditional cultural norms. Hence, in order to design successful policies to reduce child marriage – a goal that has received increasing attention because of its potentially large impact on human capital accumulation and economic development (Wodon, Male, Nayihouba, et al., 2017) – it is crucial for economists and policy makers to understand the economic role of traditional cultural norms. More generally, our findings point to the importance of cultural norms in influencing the external validity of natural experiments and of replicating empirical and experimental analyses in different contexts to better understand the economic mechanisms behind empirical results.

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Tables and Figures

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

	SSA			India		
	Obs.	Mean	Std. Dev.	Obs.	Mean	Std. Dev.
Panel A: Full Sample						
Unique Individuals in Sample	326,645			66,466		
Age	2,461,176	16.12	3.28	433,187	15.55	2.95
Percent Married Between Ages 12 and 24	2,461,176	11.34	31.71	433,187	14.53	35.24
Percent Married Between Ages 12 and 17	1,799,037	8.76	28.27	329,586	10.91	31.17
Percent with First Child Between Ages 12 and 24	2,754,577	9.75	29.67	560,616	10.24	30.32
Percent with First Child Between Ages 12 and 17	1,931,808	5.56	22.92	374,059	5.37	22.54
Percent Drought	2,461,176	16.12	36.77	433,187	15.26	35.96
Percent Hindus				432,801	75.03	43.29
Panel B: High BP $\geq$ 50% Countries						
Unique Individuals in Sample	271,175					
Age	2,061,786	16.15	3.30			
Percent Married Between Ages 12 and 24	2,061,786	11.24	31.59			
Percent Married Between Ages 12 and 17	1,507,707	8.76	28.27			
Percent with First Child Between Ages 12 and 24	2,309,491	9.63	29.51			
Percent with First Child Between Ages 12 and 17	1,621,493	5.53	22.85			
Percent Drought	2,061,786	16.01	36.67			

Note: Table shows summary statistics for the main Sub-Saharan Africa (SSA) and India regression samples, consisting of women aged 25 or older at the time of interview. Observations are at the level of person × age, where age ranges from 12 to 24 or age of first marriage, whichever is earlier. Results for SSA are weighted by the population-adjusted survey sampling weights.

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***	-0.08**	-0.11***	-0.06*	-0.12***	-0.12***	-0.11***	-0.08**	-0.12***	-0.07	-0.12***
	(0.03)	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)	(0.02)	(0.04)	(0.03)	(0.04)	(0.04)	(0.02)
Mean Production (Kilotons)	775.2	429.3	324.7	255.7	152.3	1,803.8	678.3	400.3	385.8	309.4	92.4	1,724.4
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
The 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 SSA countries in the FAOStat database, whereas "DHS SSA Only" columns include the SSA countries available in the DHS and used in our main analysis. In the columns labeled "Average", the dependent variable is the log of the sum of total production of main crops reported (maize, sorghum, millet, rice, and wheat) divided by the total area harvested for those crops. 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)	(2)	(3)	(4)	(5)	(6)
	Rice	Wheat	Jowar	Maize	Bajra	Average
Drought	-0.18***	-0.05***	-0.18***	-0.04**	-0.19***	-0.16***
	(0.02)	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)
Mean Production (Tons)	143.7	96.4	43.2	20.4	24.5	291.6
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
The 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. In the columns labeled "Average", the dependent variable is the log of the sum of total production of main crops reported (rice, wheat, jowar, maize, and bajra) divided by the total area harvested for those crops. The crops (except for "Average") are sorted by total annual 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: Effect of Droughts on the Timing of Marriage

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

Note: * p<0.1, ** p<0.05, *** p<0.01
Table shows OLS regressions for the Sub-Saharan Africa (SSA) and India full regression samples: women aged 25 or older at the time of interview. Observations are at the level of person × age (from 12 to 24 or age of first marriage, 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. Regressions for SSA are weighted using population-adjusted survey sampling weights.

Table 5: Effect of Droughts on Child Marriages

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

Note: * p<0.1, ** p<0.05, *** p<0.01
Table shows OLS regressions for the Sub-Saharan Africa (SSA) and India full regression samples: women aged 25 or older at the time of interview. Observations are at the level of person × age (from 12 to 17 or age of first marriage, whichever is earlier). 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. Regressions for SSA are weighted using population-adjusted survey sampling weights.

Table 6: Effect of Drought on Early Marriages, by Marriage Payment Custom in Sub-Saharan-Africa

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

Note: * p<0.1, ** p<0.05, *** p<0.01
Table shows OLS regressions for Sub-Saharan-Africa (SSA): women aged 25 or older at the time of interview. 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 3-4) and 80% (columns 5-6). Column 7 presents results for Eritrea, the only country in our sample with a widespread dowry tradition. Observations are at the level of person $\times$ age (from 12 to 17 or age of first marriage, whichever is earlier). Robust standard errors (in parentheses) are clustered at the grid cell level. All regression specifications include grid cell fixed effects. Results are weighted using population-adjusted survey sampling weights (columns 1-6). See Table A1 for traditional marriage customs by country.

Table 7: Effect of Droughts on Early Marriages, by Religion in India

	(1)	(2)
Drought × Hindu	-0.0053***	-0.0045**
	(0.0019)	(0.0021)
Drought × Muslim	0.000014	-0.0021
	(0.0057)	(0.0061)
Drought × Others	-0.0034	-0.0040
	(0.0032)	(0.0034)
Birth Year FE × Religion FE	Yes	Yes
Age FE × Religion FE	Yes	Yes
State FE × Cohort FE	No	Yes
N	329,294	329,294
Adjusted R^2	0.085	0.069

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 12 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. Irrigation data for districts in 19 states is provided by the District Level Database Documentation.

Table 8: Effect of Weather Shocks on Early Fertility in Sub-Saharan-Africa and India

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

Note: * p<0.1, ** p<0.05, *** p<0.01
Table shows OLS regressions for Sub-Saharan Africa (SSA) and India: women aged 25 or older at the time of interview. Observations are at the level of person × age (from 12 to 17 or age of first 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 9: Long-run Effects of Droughts in Sub-Saharan-Africa and India

	BP $\geq$ 50%		BP $<$ 50% and Eritrea		India	
	(1) age of marr.	(2) n. children	(3) age of marr.	(4) n. children	(5) age of marr.	(6) n. children
N. of droughts ages 12-14	-0.045	0.040**	0.048	-0.068*	0.00058	0.0063
	(0.029)	(0.018)	(0.056)	(0.036)	(0.032)	(0.023)
N. of droughts ages 15-17	-0.054**	0.044***	0.011	-0.077***	0.050*	-0.024
	(0.027)	(0.015)	(0.053)	(0.028)	(0.031)	(0.023)
N. of droughts ages 18-20	-0.043	0.043***	-0.060	-0.074***	-0.012	-0.035
	(0.028)	(0.015)	(0.043)	(0.026)	(0.034)	(0.024)
N. of droughts ages 20-24	-0.053**	0.039**	-0.052	-0.051**	-0.020	-0.046**
	(0.022)	(0.015)	(0.035)	(0.023)	(0.027)	(0.022)
Birth Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Current Age FE	Yes	Yes	Yes	Yes	No	No
Country FE	Yes	Yes	Yes	Yes	No	No
N	252,666	271,175	57,026	58,975	66,466	66,466
Adjusted R^2	0.19	0.42	0.063	0.35	0.23	0.26

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 1-3 present the results for SSA countries with low prevalence of bride price (BP) custom ($<$ 50%), while columns 4-6 present results for those with high BP custom, defined based on thresholds of 50%. Robust standard errors (in parentheses) are clustered at the grid cell level. All regression specifications include grid cell fixed effects. Results are weighted using population-adjusted survey sampling weights. See Table A1 for traditional marriage customs by country.

Table 10: Marriage Characteristics by Rainfall Realization at the Time of Marriage

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

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

Table 11: Weather Shocks and Marriage Payments for Child Marriage in India and Indonesia

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

Note: * p<0.1, ** p<0.05, *** p<0.01
Table shows OLS regressions based on deck 8 and 215 of the REDS data (col.1-3) and from the IFLS in Indonesia (col. 4-6). Observations are at the level of a marriage. Robust standard errors (in parentheses) are clustered at the district level in India and province in Indonesia. P-values in square brackets are wild bootstrapped clustered at the province level. All regression specifications include district or province fixed effects.

Figure 1: Equilibrium outcomes

(a) Sub-Saharan Africa (b) India

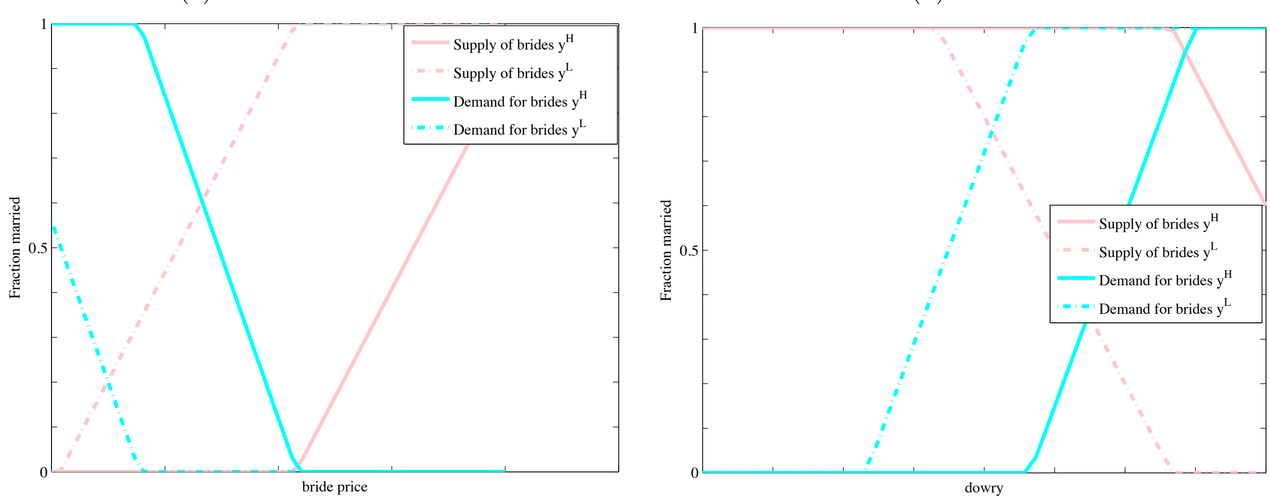
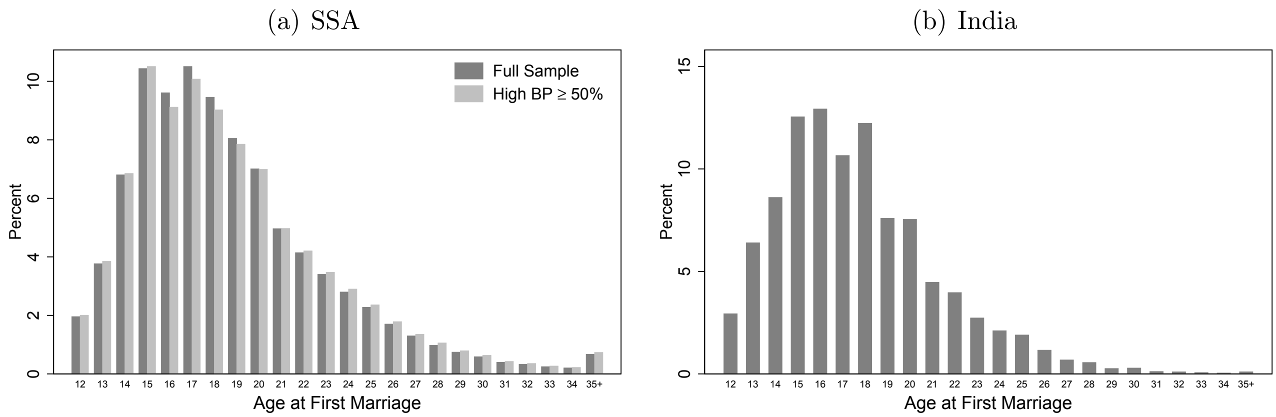
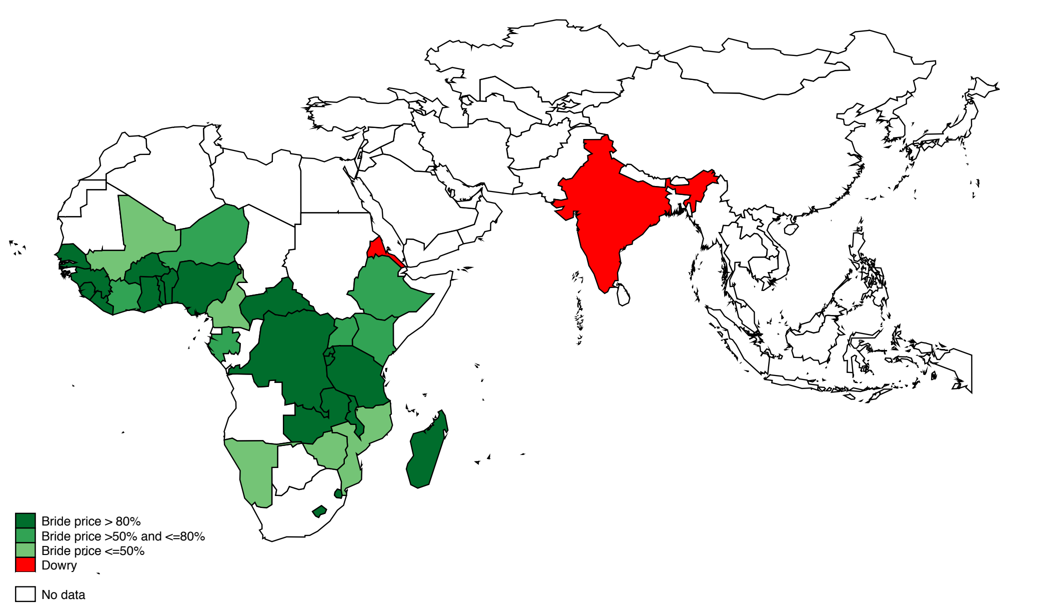


Figure 2: Distribution of the Ages at First Marriage



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.

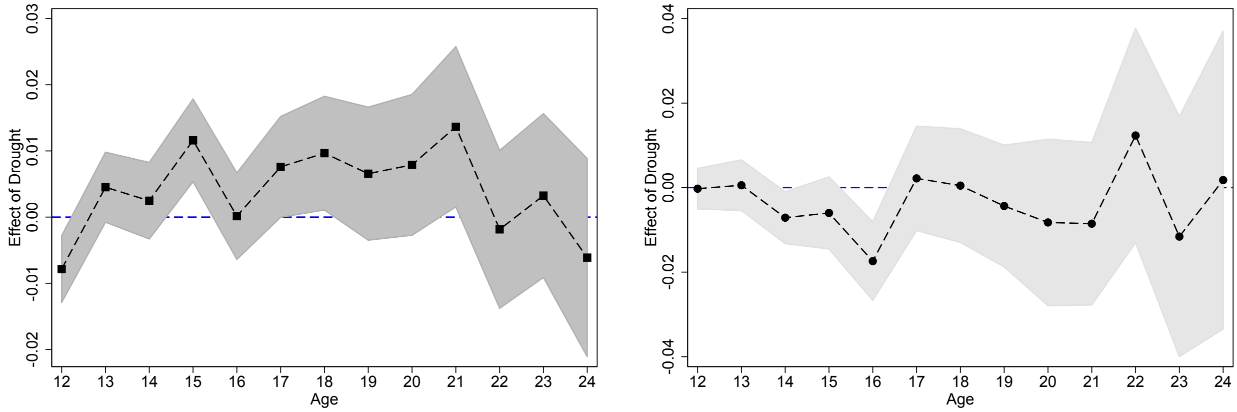
Figure 3: Map of marriage payment traditions by country in the main sample



Note: Data on bride price prevalence from *Ethnomaps*.

Figure 4: Effect of Droughts on Marriage by Age

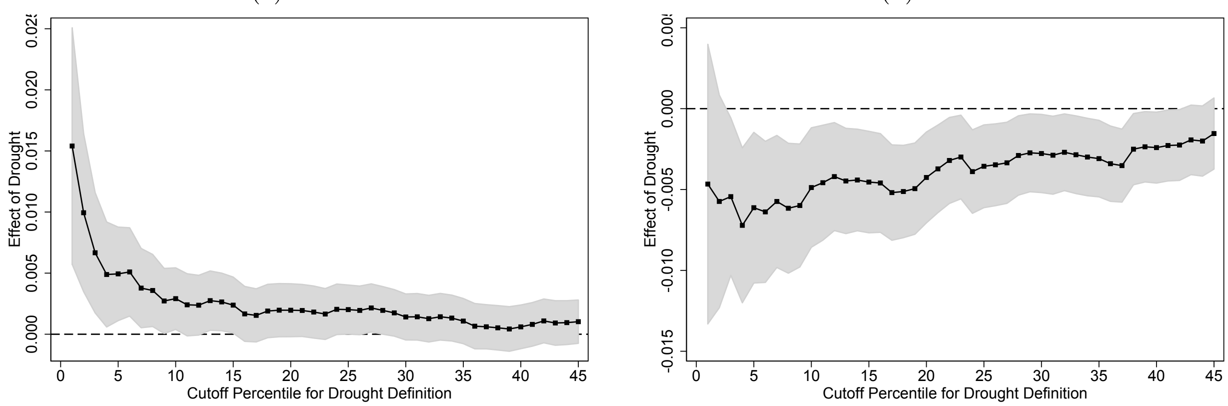
(a) SSA (b) India



Note: Figure shows the Effect of Droughts 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

(a) SSA (b) India



Note: Figures show the point estimates of the Effect of Droughts on early marriages, estimated using OLS regressions for the Sub-Saharan Africa (SSA) and India full regression samples: women aged 25 or older at the time of interview. The different points represent different definitions of drought based on the percentile of rainfall in a grid cell (SSA) or district (India) in a given year, relative to the fitted long run rainfall (gamma) distribution in that grid cell or district. The 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 15th percentile of the long-run rainfall distribution.

A Appendix Tables and Figures

Table A1: Traditional Marriage Customs in Sub-Saharan Africa

Country	% bride price	Country	% bride price
Benin	91%	Mali	93%
Burkina Faso	83%	Mozambique	44%
Burundi	99%	Namibia	58%
Cameroon	93%	Niger	100%
Central African Republic	65%	Nigeria	91%
Eritrea	45%	Rwanda	100%
Ethiopia	66%	Senegal	98%
Gabon	74%	Sierra Leone	99%
Ghana	94%	Swaziland	97%
Guinea	95%	Tanzania	81%
Ivory Coast	69%	Togo	62%
Kenya	100%	Uganda	97%
Lesotho	100%	Zaire	84%
Liberia	98%	Zambia	19%
Madagascar	13%	Zimbabwe	87%
Malawi	15%		

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

Table A2: List of Data Sets and Sources

Region/ Country	Data Topic	Source	Year
Sub-Saharan Africa	Marriage	Demographic and Health Survey (DHS)	1994-2014
	Crop Yield	FAOStat database	1960-2010
	Conflict	UCDP/PRIO Armed Conflict Dataset	1946-2015
India	Marriage	Demographic and Health Survey (DHS)	1998-1999
	Marriage	India Human Development Survey (IHDS)	2005
	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	Bride price	Indonesia Family Life Survey (IFLS)	2000, 2007
	Weather	University of Delaware (UDel)	1900-2010
	Population	World Development Indicators (WDI)	1990-2012

Table A3: 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 A4: 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 A5: Marriage migration in Africa and in India

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

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

Table A6: Marriage migration patterns by rainfall realization at the time of marriage

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

Note: * $p<0.1$, ** $p<0.05$, *** $p<0.01$
Results for SSA and India full regression samples up to age 24. 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. Regressions for SSA are weighted by population-adjusted survey sampling weights.

Table A7: Effect of Weather Shocks on the Timing of Marriage in Malawi and Zambia, by Traditional Bride Price Practice of the Ethnic Group

	Malawi			Zambia		
	(1) All	(2) No BP	(3) BP	(4) All	(5) No BP	(6) BP
Drought	0.00066	0.00019	0.00011	0.0017	-0.0012	0.0094*
	(0.0024)	(0.0027)	(0.0066)	(0.0025)	(0.0032)	(0.0053)
Birth Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Age FE	Yes	Yes	Yes	Yes	Yes	Yes
N	137,037	109,176	17,140	73,169	43,668	11,913
Adjusted R^2	0.058	0.054	0.078	0.065	0.065	0.060

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 12 to 17 or age of first marriage, whichever is earlier). The data is merged with Murdock's *Ethnographic Atlas* (1957). See Brioschi 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.

Table A8: Effect of Weather Shocks on the Timing of Fertility in Sub-Saharan-Africa and India

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

Note: * p<0.1, ** p<0.05, *** p<0.01
Table shows OLS regressions for Sub-Saharan Africa (SSA) and India: women aged 25 or older at the time of interview. Observations are at the level of person × age (from 12 to 24 or age of first 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 A9: Marriage Characteristics by Rainfall Realization at the Time of Marriage in India: Combining DHS and IHDS

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

Note: * p<0.1, ** p<0.05, *** p<0.01
results use both the India DHS from 1998 and the IHDS from 2004-2005. Robust standard errors (in parentheses) are clustered at thedistrict level (India). All regression specifications include grid cell (SSA) or district (India) fixed effects. Results for SSA are weighted by population-adjusted survey sampling weights.

Table A10: Association Between Rainfall Levels and Child Marriage

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

Note: * p<0.1, ** p<0.05, *** p<0.01
Table shows OLS regressions for the Sub-Saharan Africa (SSA) and India full regression samples: women aged 25 or older at the time of interview. Observations are at the level of person × age (from 12 to 17 or age of first marriage, whichever is earlier). 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. Regressions for SSA are weighted using population-adjusted survey sampling weights.

Table A11: Effect of Droughts and Floods on Child Marriage

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

Note: * p<0.1, ** p<0.05, *** p<0.01
Table shows OLS regressions for SSA and India: women aged 25 or older at the time of interview. Observations are at the level of person × age (from 12 to 17 or age of first marriage, whichever is earlier). 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). Regressions for SSA are weighted by population-adjusted survey sampling weights.

Table A12: Effect of Rainfall Shocks by Quintile on the Timing of Marriage

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

Note: * p<0.1, ** p<0.05, *** p<0.01
Table shows OLS regressions for the Sub-Saharan Africa (SSA) and India full regression samples: women aged 25 or older at the time of interview. Observations are at the level of person × age (from 12 to 17 or age of first marriage, whichever is earlier). 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. The regression for SSA is weighted using population-adjusted survey sampling weights.

Table A13: Current, Lag, and Future Droughts and the Timing of Marriage

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

Note: * p<0.1, ** p<0.05, *** p<0.01
Table shows OLS regressions for the Sub-Saharan Africa (SSA) and India full regression samples: women aged 25 or older at the time of interview. Observations are at the level of person × age (from 12 to 17 or age of first marriage, whichever is earlier). 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. Regressions for SSA are weighted using population-adjusted survey sampling weights.

Table A14: Robustness to Specification and Sample

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

Note: * p<0.1, ** p<0.05, *** p<0.01
Table shows OLS regressions with different weight and sample specifications for the Sub-Saharan Africa (SSA) full regression sample: women aged 25 or older at the time of interview. Observations are at the level of person × age (from 12 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 using population-adjusted survey sampling weights.

Table A15: Effect of Drought on the Timing of Marriage in India: DHS and IHDS Data

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

Note: * p<0.1, ** p<0.05, *** p<0.01
Table shows OLS regressions using DHS and IHDS surveys in India. Each regression sample consists of women aged 25 or older at the time of interview. Observations are at the level of person × age (from 12 to 17 or age of first marriage, whichever is earlier). Robust standard errors (in parentheses) are clustered at the district level. All regression specifications include district fixed effects. Regressions in columns 5 and 6 are weighted using population-adjusted survey sampling weights.

Table A16: Effect of Drought on the Timing of Marriage in India by Irrigation Intensity and Bank Development

	(1)	(2)	(3)	(4)
Drought × Low Irrig	-0.0060**			
	(0.0026)			
Drought × High Irrig	0.0016			
	(0.0028)			
Drought × Low Banking		-0.0058**	-0.0058**	-0.0056**
		(0.0025)	(0.0025)	(0.0023)
Drought × High Banking		-0.0028	-0.0029	-0.0028
		(0.0019)	(0.0019)	(0.0020)
Birth Year FE × Low Banking FE	No	Yes	Yes	Yes
Age FE × Low Banking FE	No	Yes	Yes	Yes
Birth Year FE × Low Irrig FE	Yes	No	No	No
Age FE × Low Irrig FE	Yes	No	No	No
N	247,038	329,586	329,586	329,586
Adjusted R^2	0.084	0.085	0.085	0.085

Note: * p<0.1, ** p<0.05, *** p<0.01
Table shows OLS regressions using additional surveys in India. Each regression sample consists of women aged 25 or older at the time of interview. Observations are at the level of person × age (from 12 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.

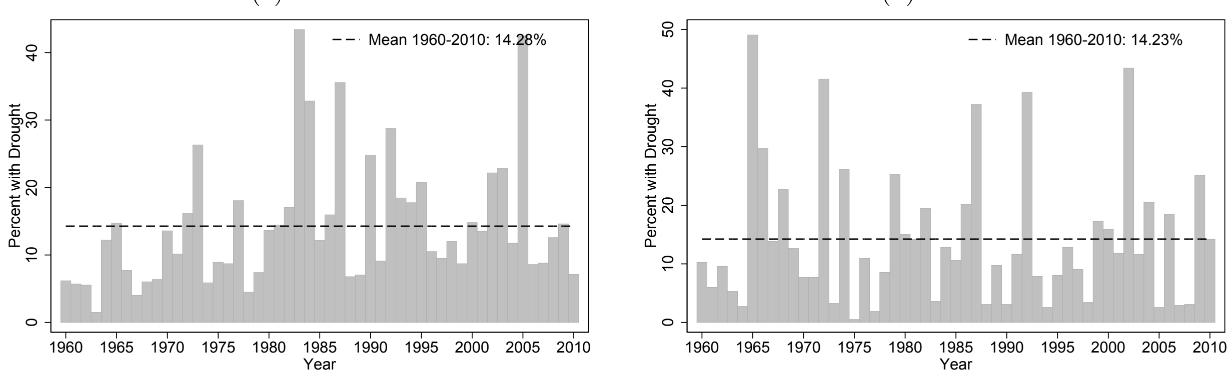
Table A17: P-values for alternative clustering methods for table 5

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

Note: * p<0.1, ** p<0.05, *** p<0.01
Table shows p-values for OLS regressions reported in table 5 for the Sub-Saharan Africa (SSA) and India full regression samples: women aged 25 or older at the time of interview. Observations are at the level of person × age (from 12 to 17 or age of first marriage, whichever is earlier). All regression specifications include grid cell (SSA) or district (India) fixed effects. Regressions for SSA are weighted using population-adjusted survey sampling weights.

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

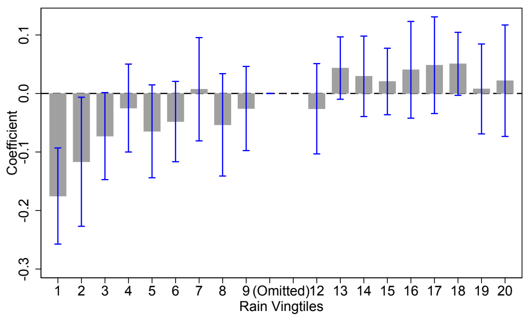
(a) SSA (b) India



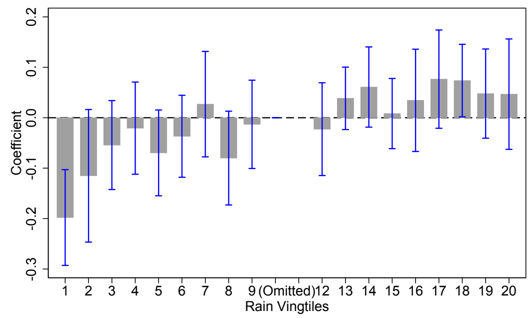
Note: Figures shows the prevalence of drought in Sub-Saharan Africa (SSA) and India, presented as the percentage of grid cells (SSA) or districts (India) with drought in each calendar year. For all the analyses in this paper, for any grid cell or district, we define a drought as having rainfall lower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

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

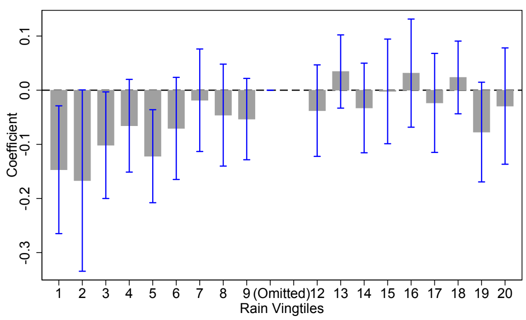
(a) Average for Main Crops



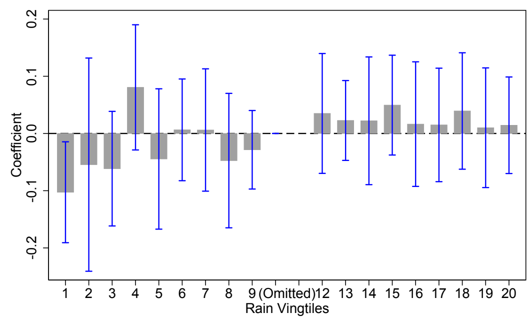
(b) Maize



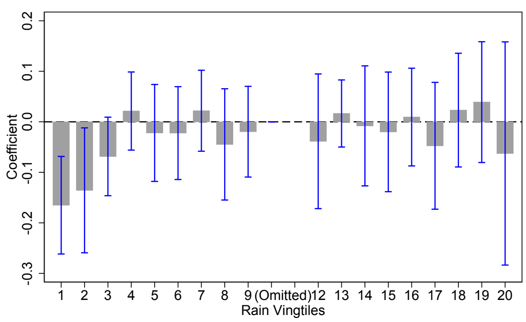
(c) Sorghum



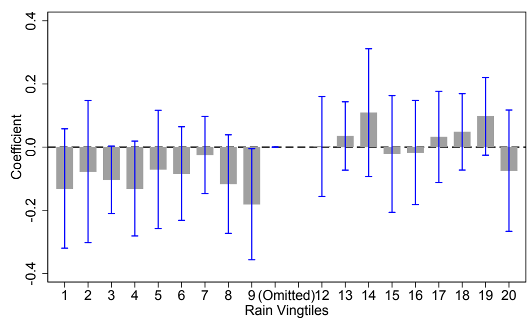
(d) Millet



(e) Rice

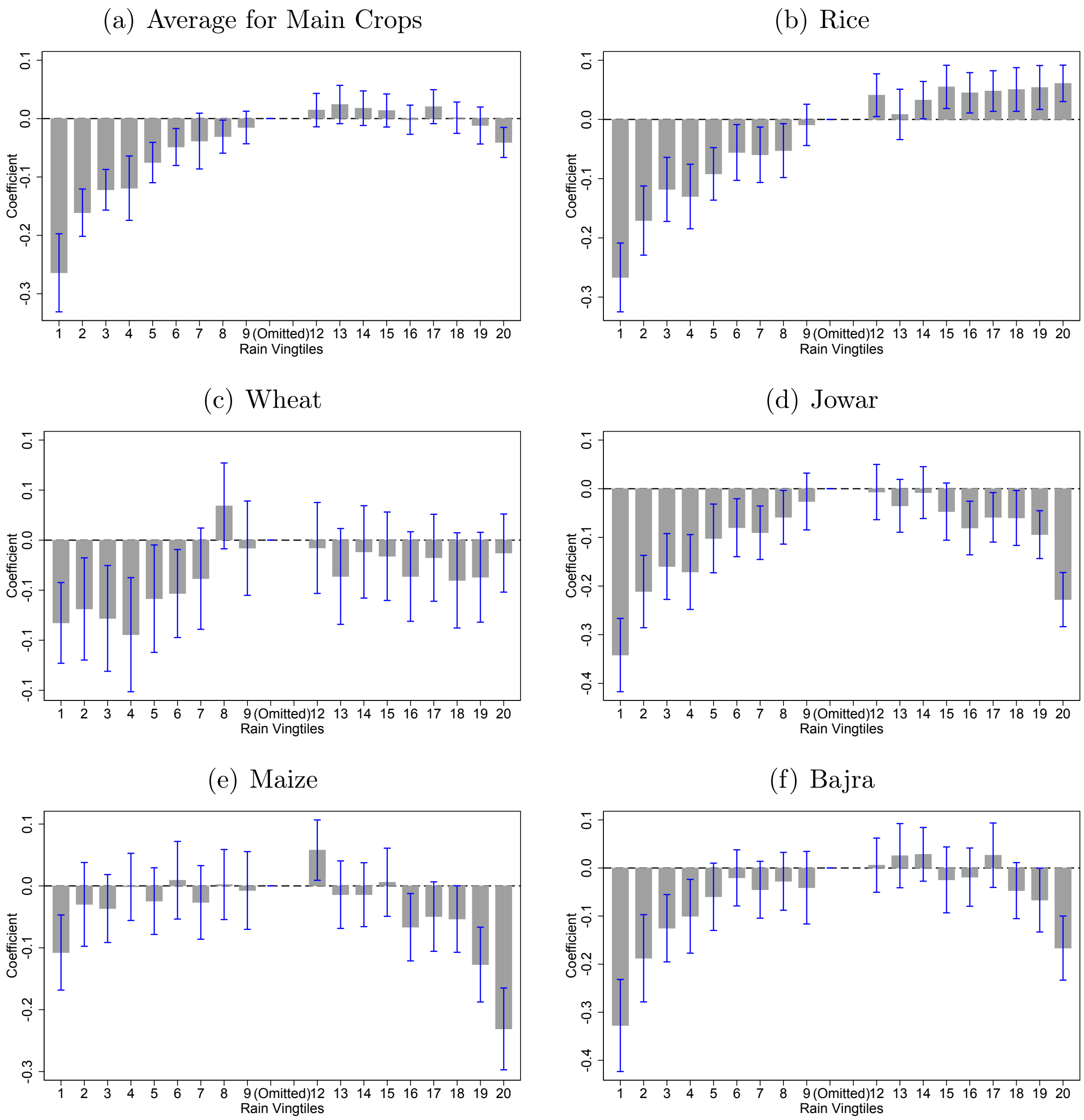


(f) Wheat



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 A3: 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.

B Theoretical appendix

B.1 Proofs

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

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

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

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

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 $H^m > 1$.

B.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 wages are 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

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

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

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

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

Hence, the demand for brides becomes

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

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

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

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

Here, $S_y^{DOW}(y_1, \tau_1) = 1 + \frac{H^f}{H^f-1}\frac{dw_1(y_1)}{dy_1}$, 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

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

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

Equilibrium quantities are :

$$Q(y_1)^{BP} = \frac{2 - H^f - H^m}{H^f - H^m}(y_1 + w_1) - \frac{H^m - 1}{H^f - H^m},$$

$$Q(y_1)^{DOW} = \frac{2 - H^f - H^m}{H^m - H^f}(y_1 + w_1) - \frac{H^f - 1}{H^m - H^f}.$$

The derivatives of these quantities with respect to aggregate income are

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

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.

More complex but more realistic is the case in which children provide labor, either on their parents' farm or in the market, and children's wages differ by gender $\{w_1^f, w_1^m\}$. Again, the marginal value of child labor is negatively affected by droughts for boys $\frac{dw_1^m(y_1)}{dy_1} \geq 0$. For girls, we consider two cases, the first in which $w_1^f > 0$ and is negatively affected by drought $\frac{dw_1^f(y_1)}{dy_1} \geq 0$

both in SSA and in India, the second in which $w_1^f < 0$ in India and $\frac{dw_1^f(y_1)}{dy_1} \leq 0$, i.e. parents can compress the daughter's consumption during a drought.

Under these conditions, we have that

$$
\begin{aligned}
S^{BP}(y_1,\tau_1) &= \frac{\tau_1}{H^f-1} - y_1 - \frac{H^f w_1^f}{H^f-1} \\
D^{BP}(y_1,\tau_1) &= 1 + y_1 + \frac{\tau_1}{H^m-1} - \frac{w^f}{H^m-1} + w_1^m \\
S^{DOW}(y_1,\tau_1) &= 1 - \frac{\tau_1}{H^f-1} + y_1 + \frac{H^f w_1^f}{H^f-1} \\
D^{DOW}(y_1,\tau_1) &= -y_1 - \frac{\tau_1}{H^m-1} + \frac{w^f}{H^m-1} - w^m
\end{aligned}
$$

The derivatives of equilibrium quantities with respect to aggregate income are

$$
\begin{aligned}
\frac{\partial Q(y_1)^{BP}}{\partial y_1} &= \frac{2-H^f-H^m}{H^f-H^m} - \frac{H^f-1}{H^f-H^m}\frac{dw_1^f(y_1)}{dy_1} - \frac{H^m-1}{H^f-H^m}\frac{dw_1^m(y_1)}{dy_1} \\
\frac{\partial Q(y_1)^{DOW}}{\partial y_1} &= \frac{2-H^f-H^m}{H^m-H^f} - \frac{H^f-1}{H^m-H^f}\frac{dw_1^f(y_1)}{dy_1} - \frac{H^m-1}{H^m-H^f}\frac{dw_1^m(y_1)}{dy_1}.
\end{aligned}
$$

In the case in which female children earn lower wages income during droughts, the decline in their wages strengthens the effect of droughts on our equilibrium results. Hence, the larger $\frac{dw_1^f(y_1)}{dy_1} \geq 0$, the stronger the decline in child marriage in dowry societies and the increase in child marriage in bride price societies. On the contrary, if girls are more productive in Sub-Saharan Africa than in India ($w_1^f \geq 0$ and $\frac{dw_1^f(y_1)}{dy_1} \geq 0$ in SSA, $w_1^f \leq 0$ and $\frac{dw_1^f(y_1)}{dy_1} \leq 0$ in India), that alone could not explain our findings.

B.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:

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

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

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

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

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

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

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

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

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

The derivatives are the following:

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

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 $D_y^{-1}(q, y_1, \Omega^m) = -\frac{D_y(\tau_1,y_1,\Omega^m)}{D_\tau(\tau_1,y_1,\Omega^m)}$.[24]

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 a bride price economy, in order to have that $Q'(y_1) < 0$, we need that $S_y^{-1,BP}(Q, y_1, \Omega^f) >$

[24] 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.

$D_y^{-1,BP}(Q, y_1, \Omega^m)$, hence that $-\frac{S_y^{BP}(\tau_1,y_1,\Omega^f)}{S_\tau^{BP}(\tau_1,y_1,\Omega^f)} > -\frac{D_y^{BP}(\tau_1,y_1,\Omega^m)}{D_\tau^{BP}(\tau_1,y_1,\Omega^m)}$ or

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

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

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

and

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

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 $S_y^{-1,DOW}(Q, y_1) < D_y^{-1,DOW}(Q, y_1)$, hence that $-\frac{S_y^{DOW}(\tau_1,y_1,\Omega^f)}{S_\tau^{DOW}(\tau_1,y_1,\Omega^f)} < -\frac{D_y^{DOW}(\tau_1,y_1,\Omega^m)}{D_\tau^{DOW}(\tau_1,y_1,\Omega^m)}$ or

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

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

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

and

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

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

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

irrespectively of the direction of the marriage payment.

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 a bride price economy 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 a dowry economy. Hence $\frac{\partial^2 \epsilon_m^*(\tau_1,y_1,\Omega^m)}{\partial \tau_1 \partial w^m} > 0$ with bride price and $\frac{\partial^2 \epsilon_m^*(\tau_1,y_1,\Omega^m)}{\partial \tau_1 \partial w^m} < 0$ with dowry.