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# Selling daughters: age of marriage, income shocks and the bride price tradition*

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**Abstract**

When markets are incomplete, cultural norms may play an important role in shaping economic behavior. In this paper, we explore whether income shocks increase the probability of child marriages in societies that engage in bride price payments – transfers from the groom to the bride's parents at marriage. We develop a simple model in which households are exposed to income volatility and have no access to credit markets. If a daughter marries, the household obtains a bride price and has fewer members to support. In this framework, girls have a higher probability of marrying early when their parents have higher marginal utility of consumption because of adverse income shocks. We test the prediction of the model by exploiting variation in rainfall shocks over a woman's life cycle, using a survey dataset from rural Tanzania. We find that adverse shocks during teenage years increase the probability of early marriages and early fertility among women.

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The relationship is stronger in villages where bride price payments are typically higher. We use these empirical results to estimate the parameters of our model and isolate the role of the bride price custom for consumption smoothing. In counterfactual exercises, we show that parents heavily rely on child marriages and bride price payments to smooth consumption. Without credit markets, bans on these practices are costly for a daughter's parents. However, ensuring access to credit limits parents' cost, making bans more likely to succeed.
*Keywords*: Child marriage, marriage payments, income shocks, consumption smoothing.

# 1 Introduction

Adolescent and child marriage is still a common practice in many countries, especially among girls. Worldwide, one third of women aged 20-24 years married before turning 18. This phenomenon is particularly widespread in the poorest regions: in Sub-Saharan Africa, for example, 40% of women aged 20-24 years are child brides (UNICEF, 2014). A direct consequence of early marriages is adolescent fertility. In Tanzania, the setting of our study, 22.8% of girls aged 15-19 had children or were pregnant in 2010 and the adolescent fertility rate of 126 (births per 1,000 girls aged 15-19) is the highest in the world (World Development Indicator, 2014).[1] The relationship between female early marriage, early fertility and poor physical and socio-economic outcomes is now well established in the literature. Child marriages are associated with reduced educational attainment, lower use of preventive health care services, lower bargaining power within the household, physical abuse and domestic violence (Jensen and Thornton, 2003; Field and Ambrus, 2008). Therefore, the eradication of child marriages is now a priority in a

[1]For comparison, adolescent fertility rates in 2010 were equal to 26 in United Kingdom, 5 in Italy and 3 in Switzerland (The World Bank, 2014).

policy agenda of many governments and international organizations such as UNICEF, UNFPA and the World Bank.[2]

Despite this evidence, little research has examined the important question of why such a practice is still so widespread in many countries. Understanding what gives rise to adolescent and child marriages is crucial to improving women's socio- economic outcomes and ultimately in promoting economic development (Duflo, 2005; Doepke, Tertilt and Voena, 2012).

This paper explores the relationship between the probability of child marriages – defined as a formal or informal union in which at least one member gets married before the age of 18 (UNICEF, 2014)– and one specific social norm, namely the bride price payment. Bride price is defined as a transfer from the groom to the family of the bride at the time of marriage. It is often interpreted as the purchase of the rights to a woman's labor and reproductive ability and is prevalent in many part of the world, including most Sub-Saharan Africa countries and in some regions of Asia (Anderson, 2007*a*). Although the bride price amount varies substantially across cultures and countries, it can constitute a sizable transfer to the bride's household. Young girls are hence a valuable asset for their family, since they can be given in marriage in exchange for a bride price. Households, hit by negative income shocks and with little access to credit market, may therefore "sell" their girls before they reach adulthood, thus exacerbating the practice of early marriages, both to obtain the bride price payment and to reduce the demand on household resources.

With this framework in mind, this paper examines the following questions:

[2] See for example, UNFPA (2012) and UNICEF (2014).

(i) are households more likely to marry off their daughters earlier when hit by adverse income shocks?
(ii) what is the role of the custom of bride price in explaining the relationship between income shocks and child marriage?
(iii) could well-functioning credit markets reduce the consumption-smoothing role of bride price and of child marriages?

To attempt to answer to these questions, we develop a simple dynamic model in which households face income variability and have no access to credit markets. A daughter may be costly to support, or can contribute to their household budget through their labor supply or home production. Upon the marriage of a daughter, parents obtain a bride price payment, which depends on her age. In this framework, a negative income shock is associated with an increase in the probability of marriage in the same period, as long as the bride price exceeds the daughter's contribution to home production.

We test this theoretical prediction using a survey dataset from Kagera, in Tanzania, the Kagera Health Development Survey 1991-2010 (KHDS), which elicited detailed information on bride price payments, and weather data from the NASA Langley Research Center. In particular, we exploit exogenous variation in rainfall shocks to study the causal effects of income shocks on the age of marriage. Negative rainfall shocks, measured as the absolute deviation of rainfall from the historical mean at the village level, are associated with sizable declines in household consumption. To examine the relationship between rainfall shocks and the timing of marriage, we match each woman to the community in which she grew up, and reconstruct the patterns of rainfall shocks that she experienced over time. Because marriage migration is prevalent among brides, we consider these rainfall deviations as idiosyncratic shocks to the village resources relative to the overall marriage market. Hence, we control for year-of-birth fixed effects to account for variation at the level of the marriage market, and for village fixed effects to account for the cross-sectional variation in the timing of marriage across the communities of origin of each woman.

We find that girls whose families were hit by a negative rainfall shock in their teenage years have a higher probability of being married by age 18. As expected, shocks that occur after that age do not have any statistically significant effect on the likelihood of early marriages. On the contrary, rainfall shocks early in life are not associated with early marriages for boys, but in line with the fact that men marry later than women on average in the data, we find weak evidence that rainfall shocks in their own communities delay marriage to later ages. In line with the idiosyncratic nature of the rainfall shocks, we do not find that these shocks affect the level of bride price paid at the time of marriage.

To disentangle the role of bride price as a consumption-smoothing device, we estimate the parameters of our dynamic model by indirect inference, targeting the responsiveness of child marriage to resource shocks, the marriage-age profile, and the distribution of consumption we empirically observe. The estimates suggest that the costs of supporting a daughter are positive and large. In counterfactual simulations, we show that child marriage and bride price are important consumption-smoothing channels for these households, and their value greatly exceeds the actual monetary amount of the bride price payment itself. Without credit markets, policies that discourage these practice are likely to generate substantial pushback from households, who rely on child marriage and bride price payments for consumption smoothing. Access to a saving technology or credit markets substantially reduce households' reliance on bride price and child marriages for consumption smoothing. These findings are relevant in light of the policy debate currently underway in Tanzania about whether to raise the legal age of marriage for women to 21 years, a reform that has been advocated by international donors and the U.S. government, but that has stalled in the domestic policy agenda (USAID, 2013).

Our paper fits into the broad literature in economics investigating the role of cultural norms – behaviors that are enforced through social sanctions – on economic development (Fernandez, Fogli and Olivetti, 2004; Fernandez and Fogli, 2009). Previous works have examined the implications of descent rules on different economic outcomes. La Ferrara (2007) tests the implication of the matrilineal inheritance rule in Ghana, where the largest ethnic group (Akan) is traditionally matrilineal, on inter-vivos transfer. She finds that children respond to the threat of disinheritance, due to the enforcement of the matrilineal rule, by increasing transfers to their parents during lifetime to induce a donation of land before the matrilineal inheritance is enforced. In a companion paper, La Ferrara and Milazzo (2012) investigate the effects of the matrilineal inheritance rule on children's human capital accumulation. Using data from Western Ghana, Quisumbing et al. (2001) explore the impact of matrilineal land tenure institutions on women's rights and the efficiency of cocoa tree resource management. A strand of this literature has focused on marriage practices (e.g., polygyny and patrilocal norms), marriage payments (dowry and bride price), and particularly on their role in development (Rosenzweig and Stark, 1989; Bishai and Grossbard, 2010; Jacoby, 1995; Gaspart and Platteau, 2010; Botticini and Siow, 2003; Ashraf et al., 2014; Bau, 2012). The latter remains a particularly worthwhile yet under-explored topic to study, because marriage payments are large and widespread transfers of wealth that affect households' saving behavior and wealth accumulation (Botticini, 1999). Tertilt (2005) and Tertilt (2006) study the relationship between polygyny, often associated with bride price, and growth. In a recent paper, Ashraf et al. (2014) show that bride price plays an important role in women's educational attainment.

The remainder of the paper is organized as follows. In section 2, we describe the tradition of marriage payment, in section 3 we develop a theoretical framework to highlight the relationship between income shocks, bride price payments and the timing of marriage. Section 4 presents the data and some descriptive statistics. In section 5, we describe the identification strategy and in section 6 we show our main results. Section 7 reports the results of the counterfactual policy simulations of the model under different assumptions about the credit markets and an extension of the model for men. Section 8 concludes.

## 2 Child marriages and bride price payments

Transfers of resources between spouses and their families are a crucial element in the marriage culture of many developing countries. Bride prices and dowries are the most well-known types of marriage payments. Bride price payment is a cash or in-kind transfer given by or on behalf of the groom to the family of the bride upon the marriage. On the contrary, dowry payments involve a transfer from the bride to the family of the groom upon the marriage.

A number of studies have attempted to explain the occurrence of bride price and dowry. In his seminal work, Becker (1981) explains the existence of dowry and bride price as means to clear the marriage market. When grooms are scarce (e.g., in monogamous and virilocal societies), brides pay dowries to grooms; when women are scarce (e.g., in polygamous societies) grooms pay bride price to brides. Another hypothesis links marriage payments to the economic value of women. Bride price customs exist in cultures where women make valuable contributions to agricultural work or other economic activity in the household (Boserup, 1970; Giuliano, 2014). In regions where women do not make such contribution, they are seen as an economic liability and hence pay a dowry at the time of marriage. A third hypothesis links marriage payments to the rights of inheritance held by women and explains the dowry's tradition as a *pre mortem* bequest made to daughters (Botticini and Siow, 2003; Maitra, 2007).

Historically, the custom of bride price has been more common than that of dowry. Less than 4 percent of the cultures listed in Murdock's Ethnographic Atlas (Murdock, 1967) have dowry payments, whereas two-thirds follow a norm of bride price (Anderson, 2007*b*). However, dowry payments have played a more significant role in the economics literature. Paying a bride price is an ancient tradition practiced throughout Africa. In the southern regions it is known as *lobola* and in East Africa as *mahari*. Beside Africa, bride price customs are also still very common in South and East Asia (Maitra, 2007).

Our context of interest in this paper is rural Tanzania. Tanzanian law governing marriages allows for bride price payments. In the data we are examining, the Kagera Health and Development Survey (KHDS) which we describe in section 4.1, bride price was paid in 81.5% of marriages, with a median amount of 102,633 Tanzanian Shillings in 2010 real terms, corresponding to 95 USD of 2014, 21% of the per capita GDP of Kagera.[3] By comparison, median household expenditure on durable goods in the 2010 KHDS sample is equal to 88,000 Shillings and median expenditure on medication and other health-related expenses is 11,000 Shillings.

The debate over the adverse consequences of the bride price custom is currently lively in Africa (see, among others, Kizito (2013), Mtui (2013)). It has been argued that this practice increases the incentive for parents to "sell off" their daughters in order to receive a bride price and decreases the probability for married women to end a marriage because their parents have to return the bride price. In a recent interview of the Thompson Reuters Foundation conducted in a village in Bagamoyo, Tanzania, a 15 years old bride says "I was very shocked because I was too young and I didn't want to get married since I was still at school. But I couldn't go against my father's

[3]Inflation data from `http://data.worldbank.org/indicator/FP.CPI.TOTL` (last accessed May 11 2016): 102,633 Tanzanian Shilling of 2010 are equal to 162,160 in 2015. Exchange rate data from `http://www.tradingeconomics.com/tanzania/currency` (last accessed May 11 2016): at exchange rate of 1814.9 for Feb 2 2015, this amount corresponds to 89 USD. In the region of Kagera, per capita GDP in 2010 is 491,713 Shillings (`http://tanzania.opendataforafrica.org/TZSOCECD2016/social-economics-of-tanzania-2016?region=1000190-kagera&indicator=1002980-gdp-per-capita-at-current-prices-tshs`, last accessed May 11 2016).

wishes who wanted to get a payment to cover his financial problem" and "My dream was to become a teacher, but I could not fulfill it as I got married and became pregnant. Now I have a child it's unlikely I will go back to school" (Kizito, 2013).

Although anecdotal evidence suggests a relationship between financial hardship and child marriages in bride price societies (Lafraniere, 2005), so far no causal evidence of the association between child marriage and idiosyncratic income shocks has been studied. In data from Zimbabwe, Hoogeveen, Van der Klaauw and Van Lomwel (2011) find that the marriage rate for daughters is higher when households experience changes in their livestock, but not when aggregate rainfall is low. Hildebrandt (2015) and Corno, Hildebrandt and Voena (2016) study the impact of aggregate rainfall shocks on child marriage in Sub-Saharan Africa and India. They show that droughts have similar effects on crop yields but opposite effects on the early marriage hazard in the two regions: in Africa, they increase the hazard into early marriage, while in India, they decrease it. This differential response may be explained by differences in the direction of traditional marriage payments in each region, with bride price being prevalent in Africa and dowry in India.

## 3 The model

In this section, we develop a simple dynamic model with incomplete markets in which households are exposed to idiosyncratic shocks to their income and cannot borrow or save. We later estimate the parameters of this structural model and use it to quantify the role of bride price and child marriages in providing consumption insurance to households that lack access to credit markets.

Decisions are made by parents, who have one daughter and obtain a bride price payment $BP_a$ upon her marriage. The bride price $BP_a$ is a function of the daughter's age. Income $y_a$ is an i.i.d. stochastic process.

Households live till time $T$ and will marry their daughter by age $A$, with $14 < A < T$.[4] Period 1 is the time of birth of the daughter, and hence we can refer to periods and ages interchangeably. Parents maximize discounted expected utility over their consumption and have a per-period utility function $u(c)$ which has constant relative risk aversion coefficient $b$ (hence, $u(c) = \frac{c^{1-b}}{1-b}$). In each period, a state of nature $s_a$ is realized, which corresponds to a realization of the i.i.d income process $y_a(s_a)$. Denote $s^a = \{s_{14}, ...s_a\}$ the history of states of nature between age 14 and age $a$. Parents observe $y_a(s_a)$ and choose consumption $c_a(s^a)$. If their daughter is unmarried (denoted as $M_{a-1}(s^{a-1}) = 0$), they choose whether or not to give her in marriage at that age $m_a(s^a) \in \{0, 1\}$. If the daughter marries, $m_a(s^a) = 1$, this results in $M_a(s^a) = 1$.

Parents allocate resources $i_a$ to their daughter, which depend on her age and need not to be positive, i.e. the daughter can contribute to the parents' consumption through her home production or her labor supply when $i_a < 0$.

[4]Given the high marriage rates in Kagera, we assume that all women will marry within a given age range. We set the initial period to age 14, when considerations on child labor are less relevant. For an analysis of child labor in the KHDS data, see **?**.

The parents solve the following problem:

$$max_{c\geq 0, m\in\{0,1\}} \qquad \sum_{a=14}^{T} \delta^{a-14} E\left[u\left(c_a(s^a)\right)\right]$$

$$s.t. \quad c_a(s^a) + i_a(1 - M_a(s^a)) \leq y_a(s_a) + BP_a \cdot m_a(s^a)$$

$$M_{13} = 0, M_A = 1.$$

For every period $t$ and state of nature $s^a$ :

$$\text{if } M_{a-1}(s^{a-1}) = 1, \text{ then } m_a(s^a) = 0$$

$$\text{if } M_{a-1}(s^{a-1}) = 0 \text{ and } m_a(s^a) = 0, \text{ then } M_a(s^a) = 0$$

$$\text{if } m_a(s^a) = 1, \text{ then } M_a(s^a) = 1, ..., M_A(s^A) = 1.$$

In this simple framework, the daughter acts as an indivisible asset and the timing of her marriage is an optimal stopping problem. The demand of brides by potential husbands is unaffected by $y_a(s_a)$, which is idiosyncratic to the bride's family. The daughter can get married in any period as long as the parents choose so. Parents invest in their daughter if $BP_a$ increases with her age $a$ or hold on to her if $BP_a$ decreases with her age in order to smooth future consumption. We examine the relationship between the realization of income in a given period $(y_a(s_a))$ and the marriage probability over the life cycle. When there is a negative income shock, the parents' marginal utility of consumption is higher, and the value of marrying the daughter and immediately obtaining the bride price payment, rather than waiting, is greater.

Our main prediction is that, as long as the bride price exceeds the value of the services provided by a daughter, a low realization of income in period

$a$ increases the probability that the daughter marries in a period. Hence, for any period $a = \{14, 15, 16, 17, 18\}$, a negative income realization increases the probability of child marriage, defined as $P(M_{18} = 1) = 1 - \prod_{\alpha=14}^{18} P(m_\alpha = 0)$, i.e. one minus the probability that the girl never marries between the ages of 14 and 18.

To obtain this prediction, consider that the parents' problem admits the following recursive formulation:

$$V_a^{M_{a-1}}(s^a) = max_{c_a \geq 0, m_a \in \{0,1\}} \qquad u(c_a) + \delta E[V_{a+1}^{M_a}(s^{a+1})|s^a]$$
$$s.t. \quad c_a(s^a) + i_a(1 - M_a(s^a)) \leq y_a(s_a) + BP_a \cdot m_a(s^a).$$

The problem can be solved backwards (Adda and Cooper, 2003). In every period between $A + 1$ and $T$, parents just consume their stochastic income. At the last marriageable age $A$, we have imposed that for every realization of the state of nature, if the daughter is not yet married, she will marry. If the daughter is married, the parents will consume their stochastic income. In every other period $a \in [14, A - 1]$, the value of marrying is equal to:

$$V_a^0(m_a = 1) = u(y_a + BP_a) + \delta E[V_{a+1}^1]$$

and the value of waiting to marry at age $a$ is equal to:

$$V_a^0(m_a = 0) = u(y_a - i_a) + \delta E[V_{a+1}^0]$$

where we omit the $s^a$ for simplicity. Hence, when $M_a = 0$, parents decide to marry off their daughter, $m_a = 1$, if and only if the value of marriage exceeds the value of waiting:

$$u(y_a + BP_a) + \delta E[V^1_{a+1}] > u(y_a - i_a) + \delta E[V^0_{a+1}].$$

A drop in income $y_a$ increases the probability of marriage at age $a$. This is because, in the absence of credit markets, the continuation values $V_{a+1}(\ )$ do not depend on $y_a$ and the strict concavity of the utility function ensures that $\frac{\partial[u(y_a+BP_a)-u(y_a-i_a)]}{\partial y_a} < 0$ as long as $i_a > -BP_a$.

In what follows, we will test this prediction using rainfall shocks as an exogenous source of variation in income. We will then structurally estimate the above model to establish the quantitative importance of credit market imperfections in determining age of marriage when bride price payments are customary.

# 4 Data and descriptive statistics

We describe below the sources of data we used in our empirical analysis and in the structural estimation.

## 4.1 Kagera Health Development Survey (1991-2010)

The main dataset we used come from the Kagera Health and Development Survey (KHDS), a survey designed by the World Bank and the University of Dar es Salaam in the Kagera region, Tanzania. The Kagera region is located in the north-western corner of Tanzania, covering an area of 40,838 square kilometers, out of which 11,885 are covered by the waters of Lake Victoria.

The KHDS involved 6 rounds of data collections between 1991 and 2010, creating a 19-years panel dataset. The survey interviewed 6,353 individuals living in 51 villages (also referred to as clusters) for the first time in 1991 and then again in 1992, 1993, 1994, 2004 and 2010, irrespective of whether they had moved out of the original village, region, or country, or were residing in a new household. Excluding those who died, 85% of all the respondents surveyed during the baseline were re-interviewed in 2010.[5]

Several features makes this dataset particularly appropriate for studying the effect of the bride price on marital outcomes. First, the last wave of the survey contains detailed retrospective information on marriage, including the date of marriage, the characteristics of the marriage (i.e. formal or informal) as well as all the cash and in-kind transfers from the groom's family to the bride's family and vice versa. Second, a fairly high share of the married respondents report that payments were made at the time of their marriage, giving us the opportunity to study the effect of the bride price custom on outcomes. Third, the large majority of the respondents in the KHDS have been married at least once (71% among respondents older than 15 year old) and this provides us a reasonable sample size to analyze. Finally, the panel nature of the data allows us to track where the respondent lived as a child, rather than her current location. This feature, together with the marriage migration that is typical in this region, allows to measure shocks that affected the family of the bride but not the one of the groom or, more generally, the marriage market.

Our final sample includes 1,250 married individuals, aged 18-46, born

[5]For additional information on the KHDS see De Weerdt et al. (2012).

between 1965 and 1991 with non-missing information on the age of marriage and on weather shocks. Given that our main outcome variable - the age of marriage - does not change across survey rounds, we use cross-sectional data, mainly from the 2010 wave (97.76%) and only a small portion from the 2004 wave (3.24%).

[Insert figure 1]

Figure 1 shows the distribution of ages of marriage separately for men and women. The average age of marriage for women is approximately 20 years, while the average age of marriage for men is 24 years. A sizable portion of women marry in their teenage years, while typically fewer men do so.

[Insert table 1]

In Tanzania, the legal minimum age of marriage for boys is 18, while girls are legally eligible to marry at 15. However, either sex can marry at 14 with court approval. The current minimum age of marriage was established by the Law of Marriage Act (LMA), adopted in 1971. The LMA governs all matters pertaining to marriage, including the minimum age of marriage, divorce procedures, and guidelines for the division of property following dissolution of marital union (USAID, 2013). In our data, the age of marriage has been computed by taking the difference between the year of marriage and the year of birth. Therefore, some measurement error is plausible.[6] For example, individuals that are recorded to be married at the age of 18 could

[6]Heaping in the age of marriage is another source of concern. Studies of comparable datasets, the Demographic and Health Surveys, find no evidence of heaping in this variable (Pullum, 2006).

have been married instead at the age of 17, if the month of the wedding is before the month of birth in the calendar year. With this in mind, we defined child marriages as a union where at least one member got married at 18 or younger. Table 1 shows summary statistics for the main variables of interest and the controls in our sample. Approximately 4% of the respondents got married in the year they turned 15 and nearly 20% of the sample reported an age of marriage below or equal to 18 years.

In table A1 in the appendix, we report the correlation between the probability of marrying by the year turning 18 or before and women's socio-economic outcomes. In line with the previous literature (Jensen and Thornton, 2003; Field and Ambrus, 2008), we found that child marriages are negatively associated to higher educational attainment, greater husband-wife age gap and higher probability to have a child by the age of 18 (column 1-3). The survey also elicited information about respondents' self-esteem and locus of control.[7] In columns 4-7 we examine whether child marriages are associated with these attitudes. Results show that girls married in the year turning 18 or before are more likely to agree to have little influence over things, to feel they are a failure or not good at all and to disagree with the fact that they can improve the situation in their life. Finally, in column 8 we create an index of "Low self-esteem" by summing up all the statements used in columns 4-7. It is very interesting to note that early marriage is positive and statistically significant correlated at 1% level with a lower degree of self-esteem. Even though it has no causal interpretation, the evidence reported in table A1

[7]The survey records agreement with the following statements: (i) "Many times you feel that you have little influence over the things that happen to you"; (ii) "All in all you are inclined to feel that you are a failure"; (iii) "At times you think you are no good at all"; (iv) "If you try hard you can improve your situation in life".

shows that child marriages are strongly correlated with a number of negative women socio-economic outcomes that are associated with gender inequality and poverty.

The other key variable for our analysis is the bride price. The bride price payment includes any transfer in cash, in livestock and in-kind made to the parents, grandparents, brothers, aunts and uncles of the bride at the time of marriage.[8] In our data, we deflated the bride price amount with the Consumer Price Index recorded in Tanzania in the year of marriage by using 2010 as a base year (The World Bank, 2015). The bride price is paid both in formal and informal marriage (about 77% of the sample) - that is when the couple starts to live together and, after a certain period of time, approach the relevant family members to formalize the marital arrangement. In this type of marriage is common for the groom to pay a "fine" for taking a bride without her family consent, which is considered as a type of bride payment (Kudo, 2015). As shown in table 1, a large share of married individuals (81%) reported that a bride price payment was made at the time of marriage. The average amount of bride price payment in the sample is 97,298 Tanzanian Shilling (about 45 USD) (Panel A). [9] By matching our data based on the ethnic group of the household head with the *Ethnographic Atlas* (Murdock, 1967), a database that provides information on the cultural norms and practices of different tribes around the world, we found that in all the ethnic groups in our sample the bride price custom is a common practice in marital arrangements. Hence, unlike Ashraf et al. (2014), we cannot exploit variation

[8]In-kind payments include clothes, blankets, banana beers, raw meat, sugar, cooking oil, milk tea, handtools, and kerosene.

[9]Respondents were asked to report the corresponding value in Tanzanian Shilling of bride prices paid in-kind or in livestock (44% of the total bride price amount).

in ethic origin to isolate the effect of bride price on outcomes. Thus, we will rely on our structural model to disentangle the role of bride price from that of the economic costs associated with raising a daughter.

In table 1, panel B, we report demographic characteristics: more than half of the sample are women and only 16% of the respondents live in urban areas. Approximately 87% (72%) of the respondents have a mother (father) with primary education and only 4.3% (17.6%) of them report a mother (father) with secondary education or higher. 20% of the respondents live in inadequate houses, with floor, outside walls and roof made by made by mud, bamboo tree or earth. The average food and total consumption per capita in the past 12 months is equal to 299,701 Tzs (about 131.5 USD) and 480,352 Tzs (about 211 USD), respectively. Food and total consumption are used in natural logarithm in the empirical analysis.

In line with our theoretical framework and with a vast literature in development economics (Dupas and Robinson, 2013; De Magalhaes and Santaeulàlia-Llopis, 2015), the majority of Tanzanian households do not seem to accumulate assets to smooth consumption. They also do not appear to rely strongly on other sources of consumption smoothing, such as cattle (Rosenzweig and Wolpin (1993)). In our data, only 34% of the parents owned livestock at the time of their children's marriage.

## 4.2 Rainfall data

In Tanzania, almost 80% of the labor force (15-64 years) is employed in the agricultural sector. At 90%, the ratio of females engaged in agriculture work is even higher (International Labor Organization, 2013). The Kagera region is not an exception. In our sample, 83% of the respondents do mention agriculture as one of the main activity carried on in the household. The main cultivated crops are banana (53.3%), coffee (about 12%), maize (11%) and cassava (9.6%). Agricultural practices strongly depend on weather patterns; therefore, variations in rainfall may result in large fluctuations in income and consumption for Tanzanian households. Because the Kagera region is bordering with Lake Victoria, Africa's largest lake, natural hazards include both flooding and drought.

We then use estimates on rainfall precipitations as a source of exogenous variation for income shocks. Rainfall data come from the Modern-Era Retrospective analysis for Research and Applications (MERRA) database at the NASA Langley Research Center.[10] MERRA is a global gridded dataset based on retrospective analysis of historical weather data obtained from a combination of weather stations as well as satellite images on the density of cold cloud cover, a reliable proxy for actual rainfall precipitation. The dataset provides daily precipitation (in millimeters) aggregated into 10 grids that are $1/2°$ in latitudes $*$ $2/3°$ in longitude (roughly 55 km $*$75 km at the equator). Daily precipitation from 1981 to 2010 are linked to our 51 baseline villages (or clusters) through GPS coordinates.

For each village, we compute the historical mean level of annual precipitations (in millimeters) during the growing seasons in Kagera (March, April,

[10]The use of weather variations as proxy for income shocks in developing countries is widespread in the literature. See Miguel, Satyanath and Sergenti (2004); Björkman-Nyqvist (2013); Dustmann, Fasani and Speciale (2015); Shah and Steinberg (forthcoming), among others. In constructing a measure that treats both extremely low and extremely high rainfall realizations as a negative shock, we also follow existing literature (Bobonis, 2009).

May and October, November, December) between 1981 and 2010. The growing season is the time of the year when weather variations matter most for cultivated plants to growth and therefore for households' consumption and income.[11] As shown in panel C of table 1, the historical annual mean level of precipitation during the growing seasons is about 812 millimeters per year. For each cluster and for each year of birth, we then compute rainfall deviations (in millimeters) from the rainfall historical mean. Our measures of rainfall shocks, called $Rainfall\,Shock\,At\,Age\ a_{i,v,y}$ is the absolute value of rainfall deviation from the historical mean experienced at age $a$ by person $i$, in village (cluster) $v$, born in year $y$. For example, the variable *Rainfall Shock, Age 18* in panel C in table 1 measures the difference (in absolute value) between the yearly millimeters of rainfall during the growing seasons in the village of residence of the respondent when she/he was 18 and the historical mean of rainfall for the same village during the growing seasons. Similarly, we compute measures of average rainfall shocks within some age ranges: 17-18, 16-18, 15-18, 19-20, 19-21 and 19-22. Therefore, the variation in our measure of rainfall shocks comes from a combination of 10 grids, 51 villages (or clusters) and 27 cohorts (1965 to 1991). This combination generates, for example, 183 different shock realizations at the age of 18 across 1,250 individuals.

[Insert figure 2(a) and 2(b)]

Figure 2(a) and 2(b) show that there is considerable variation in the

[11] Northern Tanzania has a long rainy season (*Masika*) and a short rainy season (*Vuli*). In the long rainy season, planting starts in February/ March, and harvest is in July/August. During the short rainy season planting is around October/November and harvest in January/February (United States Department of Agriculture, 2003).

average rainfall shock between 17 and 18 years and the variation holds both within village of residence and across year of birth (figure 2a) and within year of birth and across villages (figure 2b).

[Insert table 2]

In table 2, we investigate the relationship between weather shocks and consumption. Specifically, we test the effect of our measure of rainfall shocks - the absolute values of rainfall deviation from the historical mean in the growing season - on the natural logarithm of total annual per capita consumption (columns 1-5) and per capita food consumption (columns 6-10) using the KHDS panel dataset from 1991 to 2010. We run OLS regressions with year and village fixed effects.

Note that our measure of rainfall is computed between March and May and between October and December of a given year, while consumption is measured over the 12 months before the survey took place, that is between March and December. We therefore expect rainfall shocks in period $t-1$ to be more likely to influence consumption recorded in year $t$ relative to rainfall shocks measured in year $t$. Results reported in table 2 show indeed that rainfall shocks at $t-1$ are negatively correlated with the measure of consumption in our data at $t$. The coefficient on rainfall in $t-1$ is statistically significant at 1% level in all the specifications and it seems therefore a reliable measure of income shocks. This test suggests that rainfall shocks are important determinants of resources, and that they are not fully insured by the household, as they are transferred into consumption changes. The lack of a statistically significant relationship between rainfall shock in the current period and consumption suggests that households were likely not yet hit by the consequences of the contemporaneous adverse shock when answering the retrospective question on consumption. In columns 4-9 of table 2, we include in the specification the current, the previous and the shocks in the following year and show a statistically significant correlation only between weather shock at time $t-1$ and consumption measured retrospectively at time $t$. Various alternative measures of weather variation were explored (i.e., proportional change in rainfall from the previous year; the growing degree days (GDD) variation from its historical mean in each cluster) but these measures are not as strongly correlated with consumption as the ones we used.[12]

# 5 Empirical Strategy

We exploit exogenous variation in weather shocks across villages and years of birth in Tanzania to study the causal effects of income shocks on the probability of girls and boys being married by the year they turn 18 or before. Specifically, we estimate the following linear probability model:

$$Y_{i,v,y} = \alpha + \sum_{a} \beta_a Rainfall\,Shock\,At\,Age\,a_{i,v,y} + \lambda X_{i,v,y} + \delta_v + \gamma_y + \epsilon_{i,v,y} \quad (1)$$

where $Y_{i,v,y}$ takes value 1 if person $i$, in village $v$, born in year $y$, got married in the year she turns 18 or before, and 0 otherwise. $Rainfall\,Shock\,At\,Age\,a_{i,v,y}$ is our proxy for income shocks experienced at different ages and it is computed as the absolute values of the rainfall deviation from the histor-

[12] The growing degree days (GDD) is a measure of heat accumulation and it is used, for example, to predict when crop reach maturity.

ical mean in each village. $X_{i,v,y}$ is a set of individual controls which include dummies for the highest level of education of the mother and the father; a dummy equal to one if the respondent lives in urban area, 16 dummies indicating the ethnic group of the head of household and a dummy for an inadequate type of dwelling.[13] Village fixed effects ($\delta_v$) and year of birth fixed effects ($\gamma_y$) are included in the estimating equation, to capture time-invariant village characteristics (e.g., richer versus poorer villages) and time-invariant cohort characteristics (e.g., marriage reforms in some particular year) that may be related to the probability of early marriages.

Our coefficients of interest are the $\beta_a$s, which capture how income shocks affect the probability of marrying before or at age of 18: a positive coefficient indicates that an adverse income shock increases the probability of child marriage. We estimate equation (1) using OLS with standard errors clustered at the village level. We report results for the sample of married individuals, separately for women and men. In Appendix table A6, we include p-values obtained by a wild bootstrap procedure in which standard errors are clustered at the grid level (Cameron, Gelbach and Miller, 2008), to account for the spatial correlation of rainfall shocks across villages within the same grid.

[13]The type of dwelling is described by the floor, the roof and the construction material of outside walls. Inadequate dwellings are those with wall, floor and roof made by mud, bamboo tree or earth; good dwellings are those with wall, floor and roof made by iron, stone or cement.

# 6 Empirical Results

## 6.1 Child marriages and income shocks

[Insert Table 3]

Table 3 reports the estimated coefficients for equation (1) for the sample of females. We start by including the average of the adverse rainfall shocks when the respondent was 17 and 18 years (column 1). The results are clear: women exposed to adverse rainfall shocks between 17 to 18 years of age (column 1) have a higher probability of being married by the year they turn 18 or before. In terms of magnitude, a one standard deviation increase in the rainfall shock at age 17 and 18 (a decrease or an increase in rainfall relative to the historical local mean) is associated with a 7.3 percentage points higher probability of early marriage and the effect is precisely estimated at 5% level. This is a substantial effect and it is robust to the inclusion of controls for the respondent's parents' education, dummies indicating if the respondent lives in urban area and in inadequate dwellings and the ethnic group of the head of household. It is interesting to note that the coefficients on mother secondary education and above is negatively and statistically significant correlated (at 5% level) with the probability for their girls to be married by the year they turn 18 or before. In columns 2 and 3, we test the effect of average rainfall shocks between 16 and 18 years and between 15 and 18 years: the results show that the coefficients on adverse shocks remain statistically significant at 5 percent level and positively correlated with early marriages. In columns 4-6 of table 3, we check the robustness of our findings by including in the main specification rainfall shocks that occurred after the age of 18. We should not observe any significant impact of adverse rainfall shocks that hit a girl after she turned 18 on her prior marriage probability. Indeed, the coefficients on rainfall shocks that hit girls after the 18 years threshold are not statistically significant (columns 4-6). On the other hand, we confirm that women exposed to negative income shocks at 17-18 (column 4), 16-18 (column 5) and 15-18 (column 6) years have a higher probability of marrying by the year they turn 18, suggesting that current and previous shocks are a good predictors for early marriages.

[Insert Table 4]

The results for males are presented in table 4. In stark contrast, adverse income shocks do not seem to influence the likelihood of child marriages for boys: almost all the coefficients on rainfall shocks are negative but not statistically significant. This gender asymmetry is consistent with evidence from the same region in Tanzania showing that parental death affects the timing of marriage of girls, but not of boys (Beegle and Krutikova, 2007). In the appendix, table A2, we report the estimated coefficients for equation (1) showing the effect of negative income shocks separately for each year in the respondent's life cycle. Once again, women hit by an adverse income shock at the age of 17 and 18 are more likely to marry before their 18th birthday (columns 1-6), while the same evidence does not appear in the sample of males (columns 7-12).

In tables A3 and A4 in the appendix we study the persistence of the effect of income shocks on marriage probability. In particular, we look at the probability of marriage by 19 (columns 1-3), 20 (columns 4-6), 21 (columns

7-9) and 22 (column 10-12) years. In table A3, we show that the effect of adverse rainfall shocks in the women's sample persists until age 21. In table A4, we examine the sample of males and we note that adverse shocks are negatively correlated with the probability of marriage at 19, 20 and 21 in a statistically significant way. Hence, while rainfall shocks do not appear to influence the probability of child marriages among men, they do appear to delay marriage to later ages. This finding is consistent with the fact that men tend to marry later than women in this sample (as in the rest of the world), with few marriages occurring before age 18 (Figure 1).

As further robustness test, in table A5 in the appendix, we check whether rainfall shocks happened *later* in life are correlated with the probability of being married by 17 years or younger and by 16 years or younger. For both girls (columns 1-4) and boys (columns 5-8), negative rainfall shocks at 17 and 18 years do not influence the probability of marriage in the year they turn 16 or before and, similarly, negative rainfall shocks at 18 and 19 years do not influence the probability of marriage in the year they turn 17 or before.

Our main takeaway from tables 3 and 4 is therefore that adverse income shocks during and before 18 years old led to an increase in the probability of marriages by the year they turn 18 for girls but not for boys. The findings are in line with our theoretical framework: households hit by adverse income shocks are more likely to marry off their daughters to receive a bride price transfer from her future groom and to give away *costly assets* in the household. On the contrary, boys may be able to better smooth their own consumption and the consumption of their family when hit by a negative rainfall shock, for example by migrating for the season (Morten, 2013; De

Weerdt and Hirvonen, 2013; Afifi, Liwenga and Kwezi, 2014), or by marrying a younger (and cheaper) spouse or by exploiting better opportunities in the labor market.

## 6.2 Evidence on the bride price mechanism

The KHDS elicits information that allows us to test whether the relationship between income shocks and age of marriage can be partly explained by the custom of the bride price. In particular, we exploit three questions in the survey: the first one asks respondents married at least once if there were any payments agreed and made for the marriage on behalf of the groom to the bride's family, including parents, but also brothers, aunts, uncles and grandparent; the second one asks how much was it worth and the third one investigates the year of marriage. We then construct the average bride price amount received by the women living in the same village of the respondent and married before the respondent turned 15, 16, 17 or 18, respectively and we call it *Neighbors' bride price, age a*, where *a* is the age of the respondent. The idea behind this new variable is that the bride price amount received by the neighboring women may provide an indication to parents on how much they can get by "selling" (marrying) their daughter at a certain age, without being directly correlated with their daughter's characteristics (e.g. education, physical appearance, etc).

[Insert Table 5]

In table 5 we augmented the main equation (1) with the interaction between rainfall shocks in a women's life cycle and the bride price amount received by the neighboring women married before the respondent turned 15, 16, 17 or 18. Results in columns 1-3 show that the interactions between adverse shocks at 17 and 18 and the bride price amount of the neighboring woman married before the respondent turned 17 or 18 are positive and statistically significant in almost all the specifications, suggesting that girls exposed to income shocks before or at the age of 17 and 18 and living in villages where the average bride price is higher have a higher probability to be married by the year they turn 18 or before. In terms of magnitude, we find that a one standard deviation increase in the interaction between an adverse shock at age 18 and the bride price received by the neighboring women increases the probability of early marriage for girls in Kagera by 19 percentage points (column 3) (the mean and the standard deviation of the interaction term at age 18 for the sample of females is 62,355 and 95,027, respectively). This is a sizable effect and it holds also by adding controls for rainfall shocks that hit girls after 18 years old (columns 4-6).

Looking at the standalone variables, we note that, in all the specifications, the *Neighbors' bride price, age a* are negatively correlated with the probability of early marriage (although not always significant), suggesting that, when rainfall is at the historical mean, communities with higher average bride price have lower rates of early marriage.

Overall, these finding point in the direction of interpreting the bride price as a source of insurance for households exposed to income shocks in the presence of capital markets imperfections.

## 6.3 Child Fertility

[Insert Table 6]

A dramatic consequence of child marriage is child fertility. In our dataset, 31% of women have a child by age 18 (table 1). In figure 3, we plot the difference in the age of marriage and the age at first child. We note that most of the observations are around zero, suggesting that the age of marriage and age of the first birth are the same for the majority of respondents in the sample. In table 6, we test the effect of negative rainfall shocks in a women's life cycle on the probability to have a child by 18 or before. The coefficients on average rainfall shocks at 17 and 18, 16 and 18, 15 and 18 are positive in all the specification, although only statistically significant when controls for future rainfall shocks are also included (columns 4-6). By focusing on the magnitude of the effect of adverse rainfall shocks at 17 to 18 years, we found that a one standard deviation increase in shocks raises the likelihood of having a child by age 18 or before by approximately 9.2 percentage points (column 4).

## 6.4 Marriage market

In table 7, we investigate the correlation between rainfall shocks in respondent's life cycle and the amount of the bride price payment among the sample of ever-married women. If households hit by the shock are in the same marriage market we should observe a negative correlation between the shock and the bride price amount: a higher supply of brides would be associated with lower bride price payment. This does not seem to be the case.

The coefficients on rainfall shocks at different ages reported in table 7 are not statistically significant, suggesting that, in line with the setup of the model, we are able to identify idiosyncratic shocks to households that do not affect the overall marriage market.

[Insert Table 7]

Further evidence on the fact that the idiosyncratic shocks we exploit (by wave, village and year birth, as shown in figures 2a and 2b) are small relative to the size of the marriage market comes from the descriptive statistics in the KHDS. First, we observe that 73.5% of women leave their village of origin upon the marriage compared to only 12% of men: this is due to the tradition that in Tanzania, brides, after the marriage, move to live with their groom's family, again suggesting that spouses generally do not come from the same village. Second, looking at the data on migration, nearly 60% of women declare that marriage is the first reason for migrating. Using the same dataset, Hirvonen and Lilleør (2015) also document that the end of a marriage is the main reason for return migration to a woman's village of origin.

# 7 Structural estimation and counterfactual experiments

In this section, we estimate the parameters of the model described in section 3. We use the estimates to perform counterfactual simulations that allow us to asses the role of child marriage and of bride price in smoothing households' consumption in response to adverse economic shocks.

## 7.1 Parametrization

The utility function for all the households is set to be a CRRA with coefficient of relative risk aversion $b$:

$$u(c) = \frac{c^{1-b}}{1-b}.$$

The cost of raising a daughter is a polynomial function of the daughter's age and we parametrize it as the multiplier of a constant $K = e^{E[ln(C)]}$ (which corresponds to 1,624,320 Tanzanian Shillings):

$$i_a = [e_0 + e_1 \cdot a + e_2 \cdot a^2 + e_3 \cdot a^3 + e_4 \cdot a^4] \cdot K.$$

Income $y_a$ follows an i.i.d. log-normal distribution with mean $\mu$ and variance $\sigma^2$. Consistently with what we observe in the KHDS data, $\mu$ is fixed and does not vary with age.

[Insert figure 4]

Bride price evolves over time as a polynomial of degree 4 in the girl's age, which we estimate directly from the data. In the model, we parametrize the bride price as a function of a woman's age as

$$ln(BP_a) = p_0 + p_1 \cdot a + p_2 \cdot a^2 + p_3 \cdot a^3 + p_4 \cdot a^4.$$

In the data, we estimate $BP_a$ as the profile of bride price payments over a women's age of marriage in the KHDS data, shown in figure 4. The intercept is the mean natural logarithm of bride price payment at age 14. The growth rate of bride price by age is estimated as a fourth-degree polynomial without controls, with controls for the woman's education (specification #1), adding controls for parental assets (specification #2), adding wedding year dummies (specification #3) and adding controls for parental education (specification #4). Compared to the raw data, education is the observable variable that modifies the shape of the age profile of bride price the most. Additional socio-economic controls do not modify this relationship. In the structural estimation, we consider the values resulting from the fourth, most comprehensive specification.[14]

We restrict marriage to occur between age 14 and age 34, since few marriages occur outside of this window. Hence, we set $A = 34$ and $T = 42$. We set the annual discount factor $\delta$ to 0.9.

## 7.2 Structural estimation

We estimate the parameters $\boldsymbol{\theta} = \{b, e_0, e_1, e_2, e_3, e_4, \mu, \sigma^2\}$ by indirect inference (Gourieroux, Monfort and Renault, 1993). We construct an auxiliary model (whose parameters we denote as $\boldsymbol{\phi}$), and estimate its empirical counterpart in the KHDS data ($\hat{\boldsymbol{\phi}}^{data}$). We then find the structural parameters

[14]In the model, we assume that the bride price amount is uniquely determined by a woman's age, and not by other observed or unobserved characteristics. This is clearly an important simplification. The presence of unobserved characteristics related to the age of marriage would bias our estimates of the relationship between bride price amounts and the daughter's age.

that solve the following problem:

$$min_{\boldsymbol{\theta}}(\hat{\boldsymbol{\phi}}^{data} - \boldsymbol{\phi}^{sim}(\boldsymbol{\theta}))G(\hat{\boldsymbol{\phi}}^{data} - \boldsymbol{\phi}^{sim}(\boldsymbol{\theta}))'. \tag{2}$$

The vector of estimated parameters of the auxiliary model comprises of three components. First, we target the vector of probability of marriage by each age between 14 and 33: $\boldsymbol{\phi_1} = \{P(M_a = 1)\}_{a=14}^{33}$, under the assumption that $P(M_{34} = 1) = 1$. In our model, each of these probabilities is equal to:

$$\begin{aligned}
&P(M_a = 1) = 1 - \prod_{\alpha=14}^{a} P(m_\alpha = 0) \\
&= 1 - \prod_{\alpha=14}^{a} P\left(u\left(y_\alpha - i_\alpha\right) + E[V_{\alpha+1}^0] > u(y_\alpha + BP_\alpha) + \delta E[V_{\alpha+1}^1]\right).
\end{aligned}$$

Second, we set two parameters of the auxiliary model as the elasticity of female teenage marriage to consumption shocks at age 17 and 18. In the model, we estimate the following model as a linear probability model

$$\begin{aligned}
P(M_{18} = 1)_i &= \delta_1 + \psi_1 \cdot ln(C_{i,17}) \\
P(M_{18} = 1)_i &= \delta_2 + \psi_2 \cdot ln(C_{i,18}).
\end{aligned}$$

where $C_{i,a}$ is aggregate consumption of household $i$ with a daughter of age $a$, hence $C_{i,a} = y_{i,a} + BP_a m_{i,a} = c_{i,a} + i_a(1 - M_{i,a})$.

Then, we set $\boldsymbol{\phi_2} = \{\psi_1, \psi_2\}$ where

$$\psi_1 = \frac{E[ln(y_{17} + BP_{17}m_{17}) \cdot M_{18}] - E[ln(y_{17} + BP_{17}m_{17})] \cdot P(M_{18} = 1)}{Var[ln(y_{17} + BP_{17}m_{17})]}$$
$$\psi_2 = \frac{E[ln(y_{18} + BP_{18}m_{18}) \cdot M_{18}] - E[ln(y_{18} + BP_{18}m_{18})] \cdot P(M_{18} = 1)}{Var[ln(y_{18} + BP_{18}m_{18})]}.$$

In the KHDS, we estimate the relationship between the probability of child marriage and rainfall shocks, and scale it by the sensitivity of consumption to rainfall shocks:

$$P(M_{18} = 1)_i = \delta_1 + \beta_1 \cdot Shock\, at\, 17_i + \boldsymbol{\lambda_1}'\mathbf{X}_i$$
$$P(M_{18} = 1)_i = \delta_2 + \beta_2 \cdot Shock\, at\, 18_i + \boldsymbol{\lambda_2}'\mathbf{X}_i$$
$$ln(C_{i,t-1}) = \alpha + \eta \cdot Shock_{i,t-1} + \boldsymbol{\gamma}'\mathbf{X}_i + \epsilon_{it}$$
$$\boldsymbol{\phi_2}^{data} = \left\{\frac{\beta_1}{\eta}, \frac{\beta_2}{\eta}\right\}$$

where $\mathbf{X}$ is a vector of year-of-birth fixed effects, cluster fixed effects and socio-economic characteristics of the household that are not captured in the model.

Third, we target the mean and variance of the logarithm of household consumption, $\boldsymbol{\phi_3} = \{E[ln(C)], Var[ln(C)]\}$, where:

$$E[ln(C)] = E[ln(y + BP \cdot m)]$$
$$Var[ln(C)] = E[(ln(y + BP \cdot m) - E[ln(C)])^2].$$

Hence, the vector of parameters of the auxiliary model combines these three sub-vectors as $\boldsymbol{\phi} = \{\boldsymbol{\phi_1}, \boldsymbol{\phi_2},\ \boldsymbol{\phi_3}\}$. The weighing matrix in the estimation is given by the inverse of the variance-covariance matrix of the empirical estimates of the parameters of the auxiliary model $\hat{G} = Var[\boldsymbol{\phi}^{data}]^{-1}$ computed by block-bootstrap, where each village is a block.

[Insert Figure 6]

Figure 6 reports the estimated parameters of the auxiliary model in the KHDS data and the corresponding estimates from the data simulated by the model. The model closely replicates the targeted distribution of marriage age (parameters 1-20, or $\boldsymbol{\phi_1}$) and the distribution of log-consumption (parameters 23 and 24, or $\boldsymbol{\phi_3}$). However, the model accounts for most the large elasticity of the probability of marriage with respect to rainfall shocks at age 17 and 18 (parameters 21 and 22, or $\boldsymbol{\phi_2}$), but not for the whole response.

[Insert Table 8]

Table 8 reports the estimates for vector $\boldsymbol{\theta}$ and their standard errors. We estimate the coefficient of risk aversion to be quite large for these poor households, with a value of 11.312. Given the estimates for $\{e_0, e_1, e_2, e_3, e_4\}$, the resulting values of $i_a$ between ages 14 and 34 are all positive, indicating that a daughter imposes a net cost on her family of origin. In particular, the cost of supporting in a daughter aged 14 to 18 is 33.5% of average household consumption, and weakly increasing in her age. Estimated average log-income $\mu$ is 14.302, which generates a simulated average log-consumption of 14.304. The estimated variance of log-income $\sigma^2$ is 0.211, which generates a simulated variance of log-consumption of 0.208.

### 7.3 Extension: men's marriage and bride price

We use our theoretical framework to validate our empirical findings. In particular, while we found sizable effects of rainfall shocks on child marriage, we found that the relationship between the age of marriage and rainfall was weaker for men, and often not statistically significant. To examine this difference, we calibrate and solve a simple model of men's timing of marriage, having estimated the parameters of the utility function and of the income process in the prior stage.

The problem of a man is similar to the one of the parents. Life starts at age t=17. The man observes idiosyncratic income $y_t(s_t)$ and choose consumption $c_t(s^t)$. If he is unmarried, he choose whether or not to marry in that period $m_t(s^t) \in \{0, 1\}$, and the bride is 4 years younger (up to age 14, which is the lowest legal age of marriage), $a = min\{t-4, 14\}$, reflecting the average gender gap in the data. If he marries, $m_t(s^t) = 1$, which will result in $M_t(s^t) = 1$.

A bride contributes to the newly formed household consumption through a contribution $k_a$, which depends on her age. Given the setup of the model, $k$ has to always be positive for any marriage to occur: if $k$ were negative and larger than income in absolute value at any point in time, the expected utility of getting married would be equal to $-\infty$ and no man would choose to marry. Modeling divorce or repudiation is outside of the scope of this exercise.

The man budget constraint thus takes the form:

$$c_t(s^t) \leq y_t(s_t) - BP_a \cdot m_t(s^t) + k_a \cdot M_{t+1}(s^{t+1})$$

In order for marriage to occur, $k_a$ ought to be non-negative in every period, since a negative $k_a$ which in absolute value is greater than realized income would lead to negative consumption, a catastrophic event that men would always want to avoid. Hence, we calibrate the contribution of a wife to household consumption parametrized as a fourth-degree polynomial function in her age which is bounded from below at 0, and we match the marriage profile for men, $\{P(M_a = 1)\}_{a=17}^{37}$ with $P(M_{38} = 1) = 1$.

Because of low rates of child marriage, the simulated responsiveness to resource shocks at age 18 is about half the one for women in absolute value, and has the opposite sign, with negative shocks reducing the probability of child marriage. This is in line with our imprecise estimates in table 4 on the male sample. The responsiveness increases in absolute values at later ages, in line with the estimates in Appendix table A4.

## 7.4 Counterfactual simulations

Below we describe three counterfactual exercises. In the first one, we study how a household in our framework behaves when it can save and borrow. In the second, we examine the behavior of a household that does not receive bride price, under different assumptions about the availability of credit markets. In the third, we examine the behavior of a household that is banned from marrying a daughter before age 18, again under different assumptions about credit markets.

It is important to point out that these are partial equilibrium results, i.e. results that do not account for how general equilibrium responses that may affect prices and the income process. Hence, we should think of them as reflecting the behavior of one household responding to a change in its circumstances when the rest of the environment is unchanged.

### 7.4.1 Credit markets

We simulate two simple counterfactual cases, in which households have access to a savings technology but no borrowing (counterfactual A) and then to perfect credit markets (counterfactual B). This simply implies that the parents' budget constraint is modified in the following way:

$$\begin{aligned} c_a(s^a) + i_a(1 - M_a(s^a)) + A_{a+1}(s^a) &\leq y_a(s_a) \\ &\quad + BP_a \cdot m_a(s^a) + (1+r)A_a(s^{a-1}) \\ A_{T+1}(s^T) &= 0. \end{aligned}$$

We calibrate the interest rate $r$ to be equal to 12% (Bank of Tanzania, 2010). In counterfactual A, we add the constraint that assets need to be positive at all times and states of nature:

$$A_a(s^a) \geq 0.$$

In both cases, allowing for credit markets eliminates the incentives to delay marriage for precautionary reasons ("saving" through a daughter). When households can save, and also when they can save and borrow, marriage happens at age 14, as the cost of supporting a daughter is greater than the return on the bride price.

### 7.4.2 No bride price payments

In this model, banning bride price indeed reduces age of marriage: because parents no longer have incentives to invest in their daughter, age of marriage is 14 for all women. The consumption-smoothing role of the bride price is highly valuable to households. We compute the value of the bride price to households as the amount of income $x$ that makes a household with a 14-years old daughter and average income ($\bar{y}_{14} = e^{\mu+\frac{\sigma^2}{2}}$) indifferent with respect to the bride price ban:

$$V_{14}^{0,baseline}(\bar{y}_{14}(1-x)) = V_{14}^{0,no\,bride\,price}(\bar{y}_{14}).$$

Eliminating bride price payments lowers household wellbeing by an amount equivalent to 72.31% of household income in one year, while the bride price alone, at its maximum, is actually equal to just 8% of average household income.

When household can borrow and save, the value of the bride price is considerably reduced, since the practice loses its consumption-smoothing role. We compute $x$ for a household with a fourteen-years-old daughter with average savings solving

$$V_{14}^{0,baseline}(\bar{y}_{14}(1-x), E[A_{14}]) = V_{14}^{0,no\,bride\,price}(\bar{y}_{14}, E[A_{14}]).$$

We find that $x$ is equal to 5.51% of average income, i.e. the value of the bride price payment for a 14-years old.

#### 7.4.3 No child marriage

Banning child marriage limits the consumption insurance purpose of marriage. If marriage cannot occur before the daughters has turned 18, households face economic shocks without being able to reduce the family size and obtain the bride price. This policy has substantial welfare consequences for households. If the cost of $i_a$ cannot be avoided and income is sufficiently low, then consequences are catastrophic: when consumption is zero, utility reaches negative infinity. Access to credit reduces the cost of such a ban to approximately 100% of average annual income. Raising minimal age of marriage to 21 years old, as is being debated, would correspond to a one-time payment equal over three times average annual income. Hence, banning child marriage might face substantial pushback from households, that use the timing of a daughter's marriage as a consumption smoothing mechanism. However, credit markets partially mitigate the negative consequences for parents.

[Insert figure 6]

An interesting implication of banning child marriage is well captured by figure 6a, which shows the cumulated probability of marriage at each age. After the ban is no longer binding, at age 18, marriage rates do not increase immediately to the levels they would have been without the ban, but slowly adjust leading to a permanent shift in the average age of marriage, which shifts from 20.5 years old at baseline (20.7 in the KHDS data for the sample of women married between 14 and 24) to 22.2 years old. If the ban is up to age 21, average age of marriage raises to 24 (figure 6b). This pattern is due to the fact that the ban on child marriage prevented marriages that would have occurred to smooth income shocks, and these household may not choose to have their daughter marry as soon as she reaches the legal age of marriage.

# 8 Conclusions

Despite widespread condemnation, the practice of child marriages persist around the world. Its consequences, especially among women and their children, are devastating, yet its reasons are poorly understood. In this paper, we explore whether income shocks increase the probability of child marriages in societies that engage in bride price payments – transfers from the groom to the bride's parents at marriage - and that have limited access to credit markets.

We develop a simple model to show that parents who are exposed to adverse income shocks have a higher probability of marrying their daughters earlier. We test the prediction of our model by using a survey dataset from rural Tanzania and by exploiting variation in rainfall over a woman's life cycle as a proxy for income shocks: adverse shocks during teenage years increase the probability of early marriages and early fertility among women. Moreover, the relationship between rainfall shocks and child marriages is stronger in villages where the average historical bride price is higher.

We use these findings, together with the profile of age of marriage and the empirical distribution of consumption, to estimate the parameters of our model and to perform counterfactual simulations. We find that supporting daughters is costly for parents, and that timing a daughter's marriage and obtaining the bride price are valuable consumption-smoothing mechanisms.

Without credit markets, policies to ban child marriage or discourage bride price payments are likely to receive strong pushback from daughters' parents. However, when households have access to credit markets, the consumption-smoothing role of bride price and child marriage become small, and banning these practices has limited consequences on the parents' wellbeing.

# References


**Adda, Jerome, and Russell W Cooper.** 2003. *Dynamic economics: quantitative methods and applications.* MIT press.

**Afifi, Tamer, Emma Liwenga, and Lukas Kwezi.** 2014. "Rainfall-induced crop failure, food insecurity and out-migration in Same-Kilimanjaro, Tanzania." *Climate and Development*, 6(1): 53–60.

**Anderson, Siwan.** 2007*a*. "The Economics of Dowry and Brideprice." *Journal of Economic Perspectives*, 21, No. 4: 151–174.

**Anderson, Siwan.** 2007*b*. "Why the Marriage Squeeze Cannot Cause Dowry Inflation." *Journal of Economic Theory*, 137: 140–152.

**Ashraf, Nava, Natalie Bau, Nathan Nunn, and Alessandra Voena.** 2014. "Bride price and the returns to education." *Unpublished Manuscript.*

**Bank of Tanzania.** 2010. *Monthly Economic Review.*

**Bau, Natalie.** 2012. "Cultural Norms, Strategic Behavior, and Human Capital Investment." *working paper.*

**Becker, Gary.** 1981. *A Treatise on the Family.* Cambridge, MA:Harvard University Press.

**Beegle, Kathleen, and Sofya Krutikova.** 2007. "Adult Mortality And Children's Transition Into Marriage." *Policy Research Working Papers.*

**Bishai, David, and Shoshana Grossbard.** 2010. "Far above Rubies: Bride Price and Extramarital Sexual Relations in Uganda." *Journal of Population Economics*, 23(4): 1177–1187.

**Björkman-Nyqvist, Martina.** 2013. "Income Shocks and Gender Gap in education: Evidence from Uganda." *Journal of Development Economics*, 105: 237–253.

**Bobonis, Gustavo J.** 2009. "Is the allocation of resources within the household efficient? New evidence from a randomized experiment." *Journal of Political Economy*, 117(3): 453–503.

**Boserup, Ester.** 1970. *Woman's Role in Economic Development.* London:George Allen and Unwin Ltd.

**Botticini, Maristella.** 1999. "A Loveless Economy? Intergenerational Altruism and the Marriage Market in a Tuscan Town, 1415-1436." *The Journal of Economic History*, 59, No. 1: 104–121.

**Botticini, Maristella, and Aloysius Siow.** 2003. "Why Dowries?" *The American Economic Review*, 93, No. 4: 1385–1398.

**Cameron, A Colin, Jonah B Gelbach, and Douglas L Miller.** 2008. "Bootstrap-based improvements for inference with clustered errors." *The Review of Economics and Statistics*, 90(3): 414–427.

**Corno, Lucia, Nicole Hildebrandt, and Alessandra Voena.** 2016. "Weather Shocks, Age of Marriage and the Direction of Marriage Payments." *Unpublished Manuscript.*

**De Magalhaes, Leandro, and Raul Santaeulàlia-Llopis.** 2015. "The Consumption, Income and Wealth of the Poorest: Cross-Sectional Facts of Rural and Urban Sub-Saharan Africa for Macroeconomists." *Unpublished Manuscript, Bristol University and Washington University in St. Louis.*

**De Weerdt, Joachim, and Kalle Hirvonen.** 2013. "Risk sharing and internal migration." *World Bank Policy Research Working Paper*, , (6429).

**De Weerdt, Joachim, Kathleen Beegle, Helene Bie Lilleør, Stefan Dercon, Kalle Hirvonen, Martina Kirchberger, and Sofya Krutikova.** 2012. "Kagera Health and Development Survey 2010: Basic information document."

**Doepke, Matthias, Michele Tertilt, and Alessandra Voena.** 2012. "The Economics and Politics of Women's Rights." *Annual Review of Economics.*

**Duflo, Esther.** 2005. "Gender Equality in Development." *BREAD Policy Paper No. 011.*

**Dupas, Pascaline, and Jonathan Robinson.** 2013. "Why Don't the Poor Save More? Evidence from Health Savings Experiments." *American Economic Review*, 103(4): 1138–71.

**Dustmann, Christian, Francesco Fasani, and Biagio Speciale.** 2015. "Illegal migration and consumption behavior of immigrant households." *working paper.*

**Fernandez, Raquel, Alessandra Fogli, and Claudia Olivetti.** 2004. "Mothers and Sons: Preference Formation and Female Labor Force Dynamics." *Quarterly Journal of Economics*, 119(4): 1249–1299.

**Fernandez, Raquel, and Alessandra Fogli.** 2009. "Culture: An Empirical Investigation of Beliefs, Work, and Fertility." *American Economic Journal: Macroeconomics*, 1(1): 146–177.

**Field, Erica, and Attila Ambrus.** 2008. "Early Marriage, Age of Menarche and Female Schooling Attainment in Bangladesh." *Journal of Political Economy*, 116(5): 881–930.

**Gaspart, Frederic, and Jean-Philippe Platteau.** 2010. "Strategic behavior and marriage payments: theory and evidence from Senegal." *Economic development and cultural change*, 59(1): 149–185.

**Giuliano, Paola.** 2014. "The Role of Women in Society: from Pre-Industrial to Modern Times." *CESifo Economic Studies*, forthcoming.

**Gourieroux, Christian, Alain Monfort, and Eric Renault.** 1993. "Indirect inference." *Journal of applied econometrics*, 8(S1): S85–S118.

**Hildebrandt, Nicole.** 2015. "Essays in Development Economics." PhD diss. New York University Department of Economics.

**Hirvonen, Kalle, and Helene Bie Lilleør.** 2015. "Going Back Home: Internal Return Migration in Rural Tanzania." *World Development*, 70: 186–202.

**Hoogeveen, Johannes, Bas Van der Klaauw, and Gijsbert Van Lomwel.** 2011. "On the timing of marriage, cattle, and shocks." *Economic Development and Cultural Change*, 60(1): 121–154.

**International Labor Organization.** 2013. "Tanzania. Decent work country program 2013-2016."

**Jacoby, Hanan G.** 1995. "The Economics of Polygyny in Sub-Saharan Africa: Female Productivity and the Demand for Wives in Côte d'Ivoire." *Journal of Political Economy*, 103, No. 5: 938–971.

**Jensen, Robert, and Rebecca Thornton.** 2003. "The Consequences of Early Marriage in the Developing World." *Oxfam Journal of Gender and Development.*

**Kizito, Makoye.** 2013. "Child marriage in Tanzania: cash for parents, problems for girls." *Newspaper article, Thomson Reuters Foundation.*

**Kudo, Yuya.** 2015. "Female migration for marriage: Implications from the land reform in rural Tanzania." *World Development*, 65: 41–61.

**La Ferrara, Eliana.** 2007. "Descent Rules and Strategic Transfers. Evidence from Matrilineal Groups in Ghana." *Journal of Development Economics*, 83 (2): 280–301.

**La Ferrara, Eliana, and Annamaria Milazzo.** 2012. "Customary Norms, Inheritance and human capital: evidence from a reform of the matrilineal system in Ghana." *working paper.*

**Lafraniere, Sharon.** 2005. "Forced to Marry Before Puberty, African Girls Pay Lasting Price." *The New York Times.*

**Maitra, Sudeshna.** 2007. "Dowry and Bride Price." *Prepared for the International Encyclopedia of the Social Sciences, 2nd Edition.*

**Miguel, Edward, Shanker Satyanath, and Ernest Sergenti.** 2004. "Economic Shocks and Civil Conflict: An Instrumental Variables Approach." *Journal of Political Economy*, 112 (41)): 225–253.

**Morten, Melanie.** 2013. "Temporary Migration and Endogenous Risk Sharing in Village India." *Unpublished Manuscript.*

**Mtui, Janet.** 2013. "Bride Price to unborn girls deplorable custom." *Newspaper article, Daily News, Tanzania's leading online new edition.*

**Murdock, George Peter.** 1967. *Ethnographic Atlas.* Pittsburgh:University of Pittsburgh Press.

**Pullum, Thomas W.** 2006. "An Assessment of Age and Date Reporting in the DHS Surveys, 1985-2003." DHS Methodological Reports 5, Calverton, Maryland: Macro International Inc.

**Quisumbing, A., E. Panyongayong, J.B. Aidoo, and K. Otsuka.** 2001. "Land Rights in the Transition to Individualized Ownership: implications for the Management of Tree Resources in Western Ghana." *Economic Development and Cultural Change*, 50 (1): 157–81.

**Rosenzweig, Mark R, and Kenneth I Wolpin.** 1993. "Credit market constraints, consumption smoothing, and the accumulation of durable production assets in low-income countries: Investments in bullocks in India." *Journal of Political Economy*, 223–244.

**Rosenzweig, Mark R, and Oded Stark.** 1989. "Consumption smoothing, migration, and marriage: Evidence from rural India." *The Journal of Political Economy*, 905–926.

**Shah, Manisha, and Bryce Millett Steinberg.** forthcoming. "Drought of Opportunities: Contemporaneous and Long Term Impacts of Rainfall Shocks on Human Capital." *Journal of Political Economy.*

**Tertilt, Michele.** 2005. "Polygyny, fertility, and savings." *Journal of Political Economy*, 113(6): 1341–1371.

**Tertilt, Michèle.** 2006. "Polygyny, women's rights, and development." *Journal of the European Economic Association*, 4(2-3): 523–530.

**The World Bank.** 2014. "World Development Indicator."

**The World Bank.** 2015. "World Development Indicator."

**UNFPA.** 2012. "Marrying too young: End Child Marriages." *UN Population Fund.*

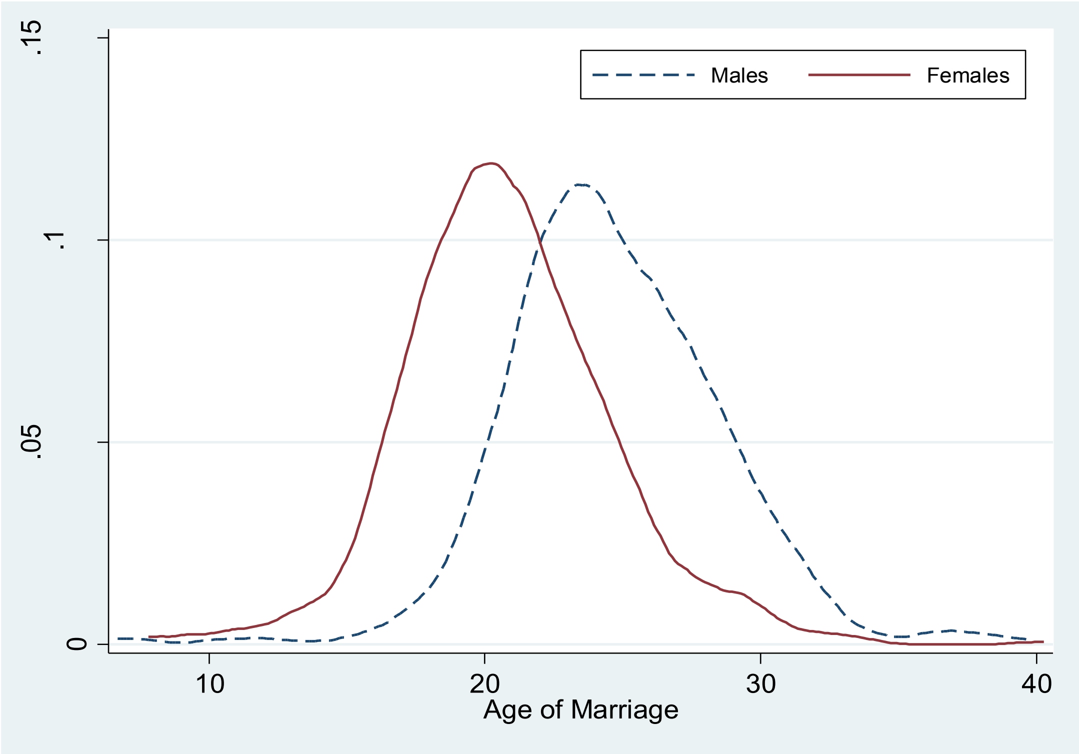
**UNICEF.** 2014. "The State of the World's Children reports." *Report.*

**United States Department of Agriculture.** 2003. "Tanzania Agricultural Seasons Production Estimates and Crop Assessment Division." *Foreign Agricultural Service.*

**USAID.** 2013. "Advocating for a change to Tanzania's legal age of marriage: efforts under the health policy initiative."

# Figures and Tables

**Figure 1: Age of marriage, by gender**

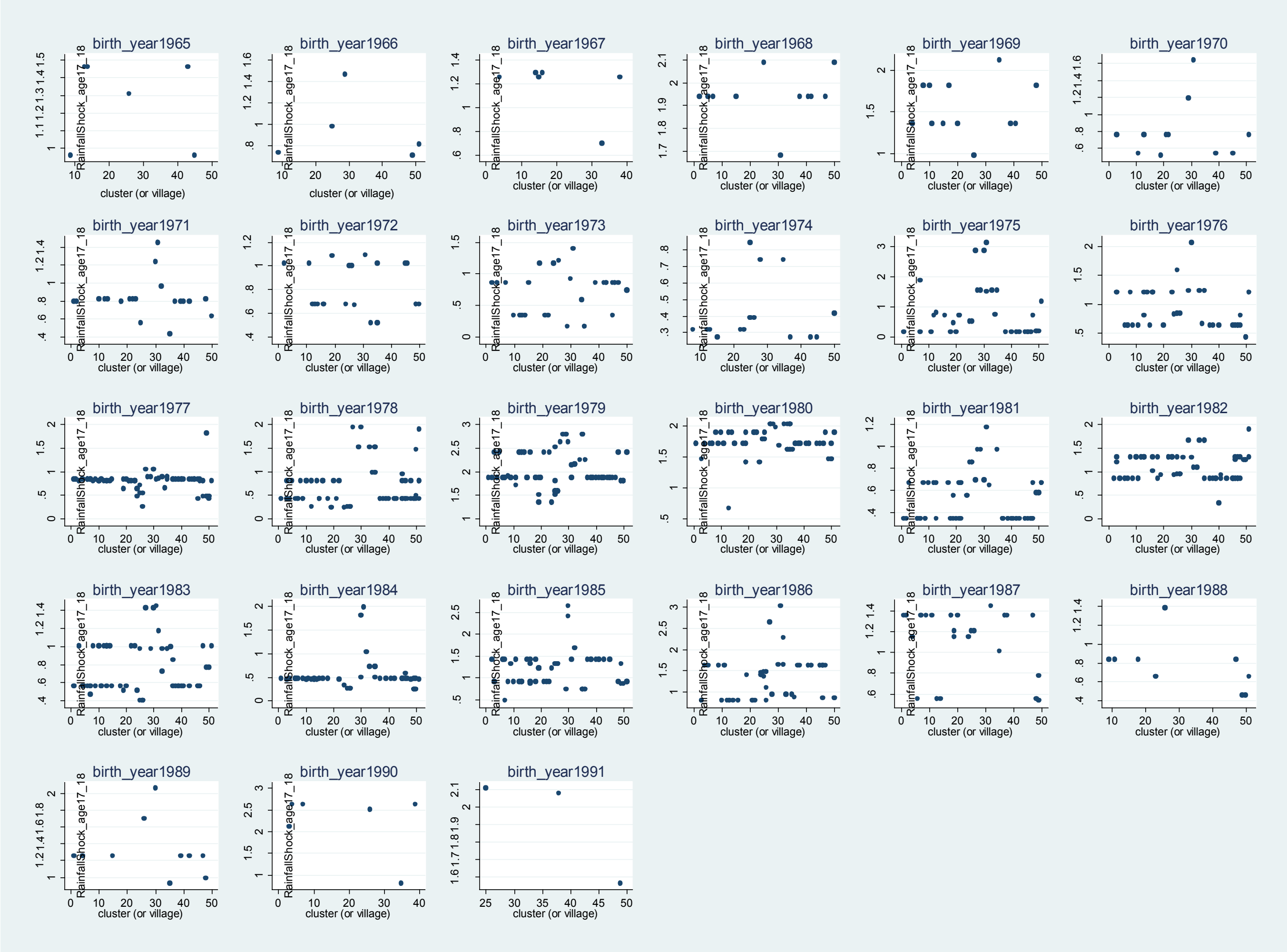



Notes: Sample of respondents with non-missing information on the age of marriage. Kernel density of distribution of ages of marriages in Kagera, Tanzania. Source: Kagera Health Development Survey.

**Figure 2a: Average rainfall shocks in the year turning 17 and 18, within cluster and across years of birth**

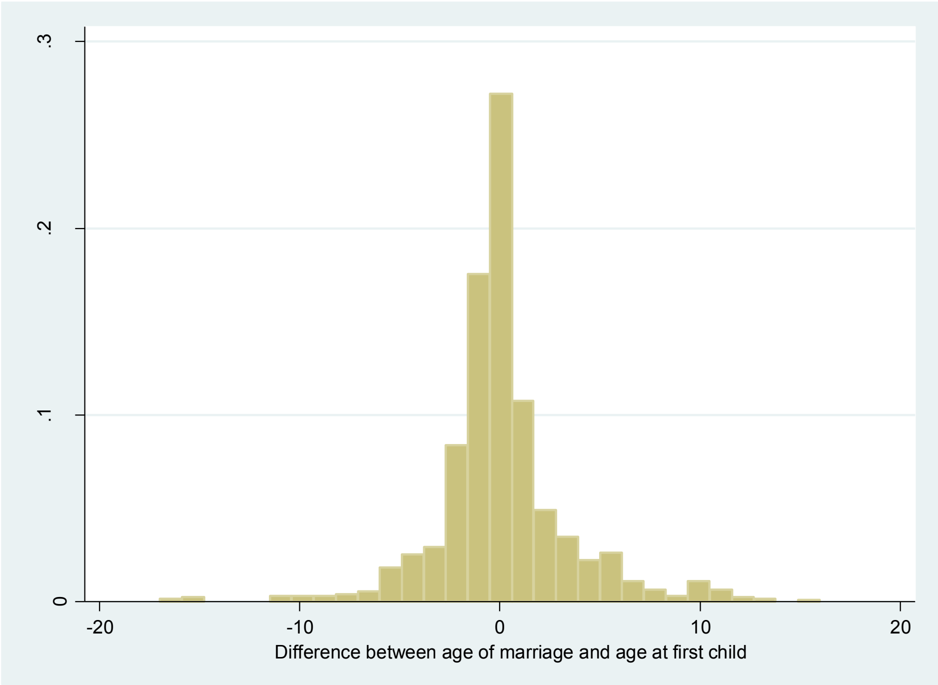
Notes: Sample of respondents with non-missing value for the age of marriage. The figure shows the variation in the rainfall shocks within cluster and across years of birth. On the horizontal axis, we report the year of birth and on the vertical axis we report the absolute value of rainfall deviation (in millimeters) from the rainfall historical mean in each cluster from 1981 to 2010 in the six months of the growing seasons (March, April, May and October, November, December) averaged in the year when the respondent is turning 17 and 18. Source: Kagera Health Development Survey for the year of birth and NASA Langley Research Centre for data on precipitation in Kagera. Grid 1 includes clusters 1,2, 4, 5, 6, 7,9,11,15,18,20,37,38, 39,40, 41, 42, 43, 44, 45,46,47, grid 2 includes clusters 3, 810, 12, 13, 14, 16, 17, 21,22, 23, 48, 51; grid 3 includes clusters 19, 24; grid 4 includes 25, 26; grid 5 includes cluster 27,30; grid 6 includes cluster 34,36; grid 7 includes clusters 28, 29,33, 35 grid 8 includes cluster 31, grid 9 includes cluster 32, and  grid 10 includes clusters 49, 50.

**Figure 2b: Average rainfall shocks in the year turning 17 and 18, across clusters and within year of birth**



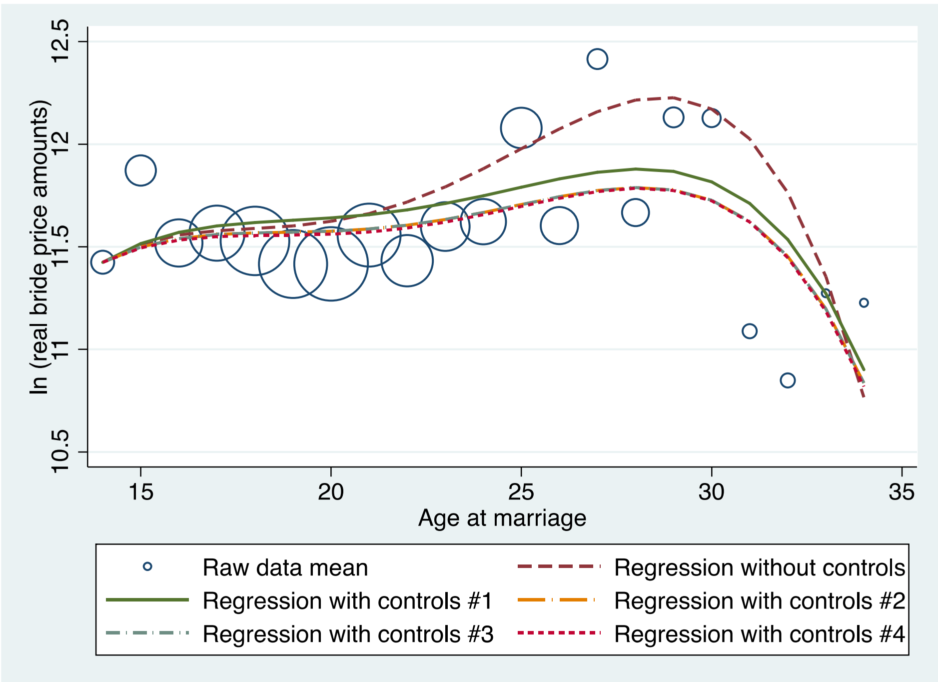

Notes: Sample of respondents with non-missing value for the age of marriage. The figure shows the variation in the rainfall shocks across clusters and within year of birth. On the horizontal axis, we report the cluster of the respondents and on the vertical axis we report the absolute value of rainfall deviation (in millimetres) from the rainfall historical mean in each cluster from 1981 to 2010 in the six months of the growing seasons (March, April, May and October, November, December) averaged in the year when the respondent is turning 17 and 18. Source: Kagera Health Development Survey for the year of birth and NASA Langley Research Centre for data on precipitation in Kagera.

## Figure 3: Difference between age of marriage and age at first child



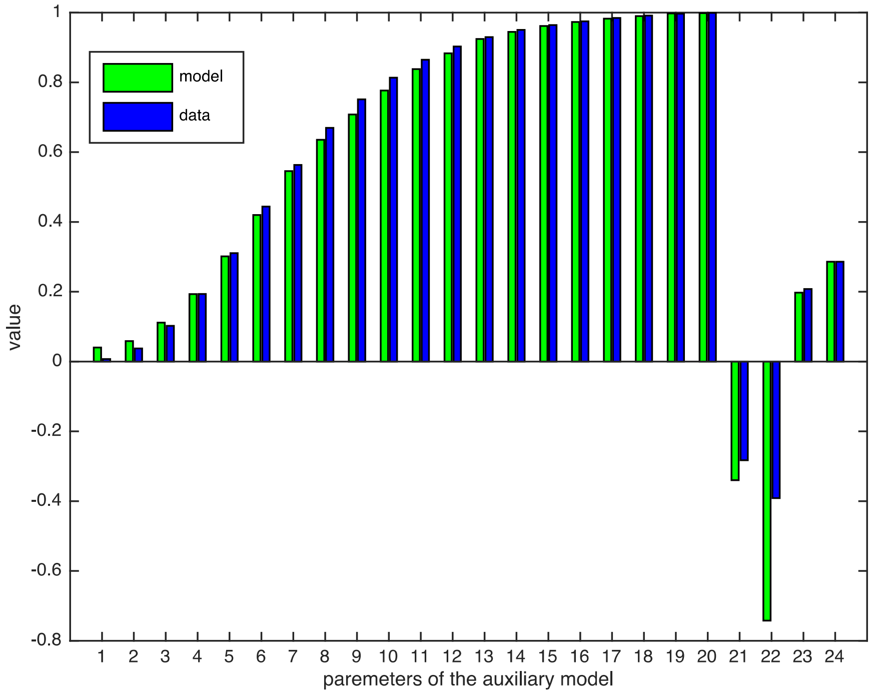

Notes: Sample of respondents with non-missing information on the age of marriage. Kernel density of distribution of the difference between the age of marriage and the age at first child. Source: Kagera Health Development Survey.

## Figure 4: Average bride price amounts earned, by daughter's age



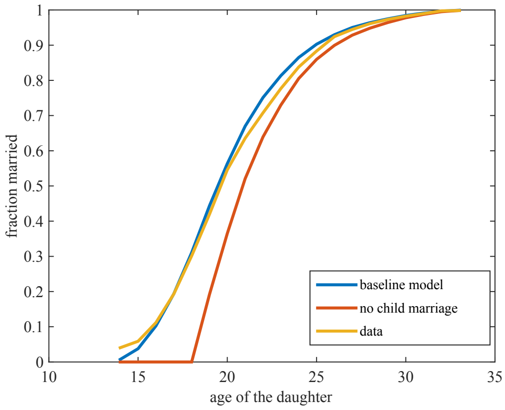

Notes: Sample of respondents with positive bride price payment. The intercept is the mean bride price payment at age 14. The growth rate of bride price by age is estimated as a fourth-degree polynomial without controls, with controls for the woman's education (specification #1), adding controls for parental assets (specification #2), adding wedding year dummies (specification #3) and adding dummies for parental education (specification #4). Source: Kagera Health Development Survey.

## Figure 5: Matching of the parameters of the auxiliary model

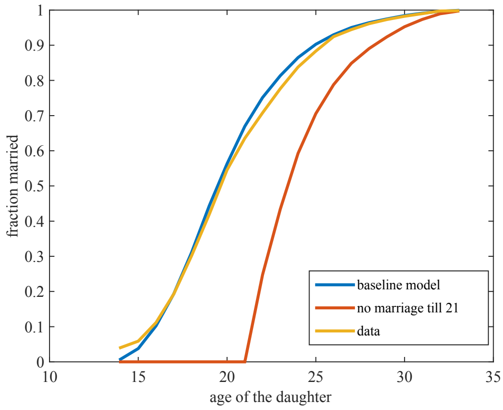



Notes: Parameters of the auxiliary model in the data and in the estimated model. Parameters 1-20 are probabilities of marriage between ages 14 and 33. Parameters 21 and 22 are the elasticity of child marriage with respect to resource shocks. Parameter 23 is the variance of the natural logarithm of household consumption. Parameter 24 is the mean of the natural logarithm of household consumption, divided by 50 for scaling purposes.

## Figure 6: Counterfactuals experiment: rising minimal age of marriage




(a)




(b)

Notes: Marriage profile by age of daughters in the KHDS data (sample of women married between age 14 and 34 in the data), in the estimated model and in a counterfactual exercise in which marriage is banned up to age 18 (panel a) and up to age 21 (panel b).

**Table 1: Summary Statistics**

| | *Mean* | *Std. Dev* | *Min* | *Max* |
|---|---|---|---|---|
| **Panel A: Marriage's characteristics** | | | | |
| Age of marriage | 21.91 | 4.267 | 6.00 | 40 |
| Marriage before or in the year turning 15 | 0.04 | 0.20 | 0.00 | 1.000 |
| Marriage before or in the year turning 18 | 0.19 | 0.39 | 0.00 | 1.000 |
| Bride price | 0.82 | 0.39 | 0.00 | 1.000 |
| Bride price amount (in TZS) | 97,298 | 132,923 | 0.00 | 1,005,000 |
| First child before or in the year turning 18 | 0.31 | 0.46 | 0.00 | 1.000 |
| **Panel B: Demographic characteristics** | | | | |
| Female | 0.59 | 0.49 | 0.00 | 1.000 |
| Urban area | 0.16 | 0.37 | 0.00 | 1.000 |
| No education (mother) | 0.09 | 0.19 | 0.00 | 1.000 |
| Primary education (mother) | 0.87 | 0.22 | 0.00 | 1.000 |
| Secondary education and above (mother) | 0.04 | 0.12 | 0.00 | 1.000 |
| No education (father) | 0.11 | 0.22 | 0.00 | 1.000 |
| Primary education (father) | 0.72 | 0.32 | 0.00 | 1.000 |
| Secondary education and above (father) | 0.18 | 0.26 | 0.00 | 1.000 |
| Bad House | 0.20 | 0.40 | 0.00 | 1.000 |
| Consumption p/c (in TZS) | 480,352 | 352,558 | 50,752 | 3,329,467 |
| Food consumption p/c (in TZS) | 299,701 | 201,234 | 25,197 | 1,600,864 |
| Parents own livestock at marriage | 0.34 | 0.47 | 0.00 | 1.000 |
| **Panel C: Rainfall Shocks (mm)** | | | | |
| Rainfall growing seasons | 812.83 | 128.64 | 549.50 | 1,188.99 |
| Rainfall shock, age 17-18 | 106.28 | 59.76 | 14.52 | 314.97 |
| Rainfall shock, age 16-18 | 103.07 | 45.49 | 20.84 | 309.42 |
| Rainfall shock, age 15-18 | 100.28 | 40.27 | 29.84 | 250.06 |
| Rainfall shock, age 19-20 | 110.69 | 61.19 | 14.52 | 314.97 |
| Rainfall shock, age 19-21 | 108.64 | 45.55 | 20.84 | 309.42 |
| Rainfall shock, age 19-22 | 108.84 | 42.48 | 29.84 | 287.39 |
| Rainfall shock, age 15 | 93.85 | 89.08 | 0.63 | 365.73 |
| Rainfall shock, age 16 | 98.43 | 89.17 | 0.63 | 379.75 |
| Rainfall shock, age 17 | 105.30 | 91.83 | 0.63 | 379.75 |
| Rainfall shock, age 18 | 107.26 | 96.00 | 0.63 | 413.01 |
| Rainfall shock, age 19 | 107.41 | 94.02 | 0.63 | 351.06 |
| Rainfall shock, age 20 | 114.43 | 96.39 | 0.63 | 413.01 |
| Rainfall shock, age 21 | 106.38 | 85.17 | 0.63 | 359.96 |
| Rainfall shock, age 22 | 108.84 | 42.48 | 29.84 | 287.39 |
| Observations | | | 1,250 | |

Notes: Sample of respondents with non-missing information on the age of marriage. "Bride price" is equal to 1 if there was a bride price payment made for the marriage; the construction material of the floor, the roof and outside walls of respondent's household describes the type of dwelling: "Bad house" are those with wall, floor and roof made by mud, bamboo tree or earth; "Consumption p/c" include all non-food expenditure (i.e. batteries, soap, umbrella, newspapers, haircuts, etc) plus expenditure in health, education, funeral and utilities and food consumption of the household divided by the household size in the past 12 months. "Food consumption" is the household food consumption divided by the household size in the past 12 months. Rainfall shocks are computed as the absolute value of rainfall deviation (in millimetres) from the rainfall historical mean in each cluster from 1981 to 2010 in the six months of the growing seasons (March, April, May and October, November, December) at each age of the respondents. Source: Kagera Health Development Survey for demographic characteristics and NASA Langley Research Center for rainfall measures.

**Table 2: Correlation between rainfall shocks and consumption**

| *Dependent variable:* | *Consumption p/c (log) (in TZS)* | | | | | *Food consumption p/c (log) (in TZS)* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| Rainfall deviation, t | 0.028 | | | 0.033 | 0.033 | 0.026 | | | 0.030 | 0.030 |
| | (0.027) | | | (0.027) | (0.027) | (0.024) | | | (0.025) | (0.024) |
| Rainfall deviation, t-1 | | -0.043*** | | -0.046*** | -0.039*** | | -0.035** | | -0.037*** | -0.035*** |
| | | (0.014) | | (0.014) | (0.013) | | (0.014) | | (0.013) | (0.013) |
| Rainfall deviation, t+1 | | | -0.034 | | -0.018 | | | -0.021 | | -0.006 |
| | | | (0.028) | | (0.026) | | | (0.025) | | (0.023) |
| Controls | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| Village Fixed Effects | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| Year Fixed Effect | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| R2 | 0.802 | 0.802 | 0.802 | 0.802 | 0.802 | 0.829 | 0.829 | 0.829 | 0.829 | 0.829 |
| Number of observations | 8,112 | 8,112 | 8,112 | 8,112 | 8,112 | 8,108 | 8,108 | 8,108 | 8,108 | 8,108 |

Notes: OLS regression on the panel dataset. Robust standard errors in parentheses, clustered at the village level. *** 1% , ** 5% , * 10% significance. Constant not displayed. "Consumption p/c" include all non-food expenditure (i.e. batteries, soap, umbrella, newspapers, haircuts, etc) plus expenditure in health, education, funeral and utilities and food consumption of the household divided by the household size in the past 12 months. "Food consumption" is the household food consumption divided by the household size in the past 12 months. Rainfall is the absolute value of rainfall deviation (in millimeters) from the rainfall historical mean in each cluster from 1981 to 2010 in the six months of the growing seasons (March, April, May and October, November, December). All the coefficients (standard errors) are multiplied by 100. Controls, as described in table 1, include dummies for mother and father highest level of education (no education, primary education and secondary/tertiary education), a dummy for respondents living in a bad house, a dummy indicating urban areas and dummies for the head of household ethnic group. Source: Kagera Health Development Survey, 1991-2010.

**Table 3: Probability of marriage by 18 and rainfall shocks, sample of females**

| *Dependent variable: 1 if married before or in the year turning 18* | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Rainfall shock, age 17-18 | 0.123** | | | 0.160** | | |
| | (0.060) | | | (0.066) | | |
| Rainfall shock, age 16-18 | | 0.132** | | | 0.157*** | |
| | | (0.054) | | | (0.060) | |
| Rainfall shock, age 15-18 | | | 0.175** | | | 0.250*** |
| | | | (0.078) | | | (0.096) |
| Rainfall shock, age 19-20 | | | | -0.049 | | |
| | | | | (0.065) | | |
| Rainfall shock, age 19-21 | | | | | -0.045 | |
| | | | | | (0.078) | |
| Rainfall shock, age 19-22 | | | | | | -0.071 |
| | | | | | | (0.095) |
| Urban | -0.177* | -0.160 | -0.160 | -0.155* | -0.132 | -0.118 |
| | (0.094) | (0.100) | (0.099) | (0.088) | (0.099) | (0.096) |
| Bad House | -0.013 | -0.019 | -0.028 | -0.011 | -0.018 | -0.022 |
| | (0.048) | (0.047) | (0.046) | (0.048) | (0.048) | (0.050) |
| Mother Primary Edu | -0.161 | -0.179 | -0.186 | -0.170 | -0.180 | -0.182 |
| | (0.114) | (0.116) | (0.116) | (0.114) | (0.117) | (0.114) |
| Mother Secondary Edu and above | -0.360** | -0.382** | -0.388** | -0.372** | -0.396** | -0.397** |
| | (0.157) | (0.161) | (0.161) | (0.158) | (0.162) | (0.161) |
| Father Primary Edu | 0.050 | 0.077 | 0.075 | 0.044 | 0.074 | 0.077 |
| | (0.085) | (0.088) | (0.088) | (0.088) | (0.095) | (0.094) |
| Father Secondary Edu and above | 0.100 | 0.130 | 0.132 | 0.093 | 0.128 | 0.131 |
| | (0.101) | (0.103) | (0.104) | (0.105) | (0.111) | (0.111) |
| Village Fixed Effects | yes | yes | yes | yes | yes | yes |
| Year of birth Fixed Effects | yes | yes | yes | yes | yes | yes |
| R2 | 0.154 | 0.154 | 0.150 | 0.151 | 0.154 | 0.156 |
| Observations | 737 | 732 | 727 | 708 | 687 | 662 |

Notes: OLS regression. Sample of females. Robust standard errors in parentheses, clustered at the village level. *** 1% , ** 5% , * 10% significance. Constant not displayed. Rainfall is the absolute value of rainfall deviation (in millimeters) from the rainfall historical mean in each cluster from 1981 to 2010 in the six months of the growing seasons (March, April, May and October, November, December). All the coefficients (standard errors) are multiplied by 100. Controls also include dummies for the head of household ethnic group. Source: Kagera Health Development Survey.

**Table 4: Probability of marriage by 18 and rainfall shocks, sample of males**

| *Dependent variable: 1 if married before or in the year turning 18* | | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Rainfall shock, age 17-18 | -0.036 | | | -0.031 | | |
| | (0.027) | | | (0.024) | | |
| Rainfall shock, age 16-18 | | -0.043 | | | -0.032 | |
| | | (0.039) | | | (0.031) | |
| Rainfall shock, age 15-18 | | | -0.045 | | | -0.043 |
| | | | (0.050) | | | (0.048) |
| Rainfall shock, age 19-20 | | | | 0.010 | | |
| | | | | (0.027) | | |
| Rainfall shock, age 19-21 | | | | | -0.010 | |
| | | | | | (0.039) | |
| Rainfall shock, age 19-22 | | | | | | -0.026 |
| | | | | | | (0.052) |
| Urban | -0.045 | -0.045 | -0.047 | -0.048 | -0.046 | -0.049 |
| | (0.033) | (0.034) | (0.034) | (0.035) | (0.035) | (0.035) |
| Bad House | -0.014 | -0.014 | -0.016 | -0.017 | -0.015 | -0.016 |
| | (0.028) | (0.029) | (0.029) | (0.030) | (0.031) | (0.031) |
| Mother Primary Edu | 0.034 | 0.031 | 0.034 | 0.046 | 0.030 | 0.032 |
| | (0.035) | (0.036) | (0.037) | (0.038) | (0.038) | (0.039) |
| Mother Secondary Edu and above | 0.167 | 0.164 | 0.162 | 0.163 | 0.155 | 0.152 |
| | (0.157) | (0.158) | (0.157) | (0.155) | (0.162) | (0.159) |
| Father Primary Edu | 0.024 | 0.027 | 0.024 | 0.008 | 0.010 | 0.005 |
| | (0.043) | (0.044) | (0.045) | (0.057) | (0.056) | (0.057) |
| Father Secondary Edu and above | 0.033 | 0.037 | 0.037 | 0.024 | 0.010 | 0.010 |
| | (0.063) | (0.061) | (0.063) | (0.070) | (0.065) | (0.066) |
| Village Fixed Effects | yes | yes | yes | yes | yes | yes |
| Year of birth Fixed Effects | yes | yes | yes | yes | yes | yes |
| R2 | 0.194 | 0.196 | 0.198 | 0.200 | 0.190 | 0.193 |
| Observations | 513 | 503 | 495 | 500 | 487 | 475 |

Notes: OLS regression. Sample of males. Robust standard errors in parentheses, clustered at the village level. *** 1% , ** 5% , * 10% significance. Constant not displayed. Rainfall is the absolute value of rainfall deviation (in millimeters) from the rainfall historical mean in each cluster from 1981 to 2010 in the six months of the growing seasons (March, April, May and October, November, December). All the coefficients (standard errors) are multiplied by 100. Controls also include dummies for the head of household ethnic group. Source: Kagera Health Development Survey.

**Table 5: Bride price and probability of marriage by 18, sample of females**

| *Dependent variable: 1 if married in the year turning 18 or before* | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Rainfall shock, age 15 * Neighbors' bride prices, age 15 | | | -0.000 | | | -0.001 |
| | | | (0.001) | | | (0.001) |
| Rainfall shock, age 16 * Neighbors' bride prices, age 16 | | 0.001 | 0.000 | | 0.001 | 0.000 |
| | | (0.000) | (0.001) | | (0.001) | (0.001) |
| Rainfall shock, age 17 *Neighbors' bride prices, age 17 | 0.001 | 0.001** | 0.001 | 0.001 | 0.001** | 0.001 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| Rainfall shock, age 18 *Neighbors' bride prices, age 18 | 0.001** | 0.002*** | 0.002** | 0.001* | 0.002** | 0.002 |
| | (0.000) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| Rainfall shock, age 19 *Neighbors' bride prices, age 19 | | | | -0.000 | 0.000 | -0.000 |
| | | | | (0.001) | (0.001) | (0.001) |
| Rainfall shock, age 20 *Neighbors' bride prices, age 20 | | | | | -0.000 | -0.001 |
| | | | | | (0.001) | (0.001) |
| Rainfall shock, age 21 *Neighbors' bride prices, age 21 | | | | | | -0.000 |
| | | | | | | (0.001) |
| Rainfall shock, age 15 | | | 1.108 | | | 1.124 |
| | | | (0.733) | | | (0.797) |
| Rainfall shock, age 16 | | 0.150 | 0.849 | | 0.245 | 0.852 |
| | | (0.535) | (0.887) | | (0.563) | (0.979) |
| Rainfall shock, age 17 | 0.083 | -0.021 | -0.128 | 0.156 | 0.366 | 0.694 |
| | (0.522) | (0.632) | (0.711) | (0.534) | (0.691) | (0.850) |
| Rainfall shock, age 18 | 0.155 | -0.071 | -0.285 | 0.126 | 0.660 | 0.759 |
| | (0.552) | (0.801) | (1.029) | (0.636) | (0.861) | (1.261) |
| Rainfall shock, age 19 | | | | -0.159 | -0.970 | -0.824 |
| | | | | (0.523) | (0.852) | (0.828) |
| Rainfall shock, age 20 | | | | | -1.299 | -1.341 |
| | | | | | (0.849) | (0.973) |
| Rainfall shock, age 21 | | | | | | 0.177 |
| | | | | | | (0.760) |
| Neighbors' bride prices, age 15 | | | -0.002* | | | -0.002* |
| | | | (0.001) | | | (0.001) |
| Neighbors' bride prices, age 16 | | -0.000 | 0.003* | | -0.001 | 0.003* |
| | | (0.001) | (0.001) | | (0.001) | (0.002) |
| Neighbors' bride prices, age 17 | -0.002* | -0.003* | -0.003 | -0.002* | -0.002 | -0.002 |
| | (0.001) | (0.002) | (0.002) | (0.001) | (0.002) | (0.002) |
| Neighbors' bride prices, age 18 | -0.000 | -0.002 | -0.003 | 0.001 | -0.001 | -0.002 |
| | (0.001) | (0.002) | (0.002) | (0.002) | (0.002) | (0.003) |
| Neighbors' bride prices, age 19 | | | | -0.002 | -0.002 | -0.001 |
| | | | | (0.002) | (0.003) | (0.003) |
| Neighbors' bride prices, age 20 | | | | | -0.000 | 0.004 |
| | | | | | (0.003) | (0.003) |
| Neighbors' bride prices, age 21 | | | | | | -0.001 |
| | | | | | | (0.003) |
| R2 | 0.180 | 0.191 | 0.233 | 0.176 | 0.192 | 0.250 |
| Number of observations | 546 | 490 | 423 | 536 | 469 | 391 |

Notes: OLS regression. Robust standard errors in parentheses, clustered at the village level. *** 1% , ** 5% , * 10% significance. Constant not displayed. Rainfall is the absolute value of rainfall deviation (in millimeters) from the rainfall historical mean in each cluster from 1981 to 2010 in the six months of the growing seasons (March, April, May and October, November, December). All the coefficients (standard errors) aremultiplied by 1000. The variables relating to neighbors' bride prices at different ages is the average bride price amount received by women living in the same village as the respondent married before the respondent turned 15 to 18, respectively. Controls, as described in table 1, include dummies for mother and father highest level of education (no education, primary education and secondary/tertiary education), a dummy for respondents living in inadequate house, a dummy indicating urban areas and dummies for the head of household ethnic group. Source: Kagera Health Development Survey.

**Table 6: Child fertility**

| *Dependent variable: 1 if 1 if first child before or in the year turning 18* | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Rainfall shock, age 17-18 | 0.114 | | | 0.154** | | |
| | (0.072) | | | (0.077) | | |
| Rainfall shock, age 16-18 | | 0.123 | | | 0.146* | |
| | | (0.077) | | | (0.076) | |
| Rainfall shock, age 15-18 | | | 0.135 | | | 0.198** |
| | | | (0.084) | | | (0.086) |
| Rainfall shock, age 19-20 | | | | 0.013 | | |
| | | | | (0.057) | | |
| Rainfall shock, age 19-21 | | | | | 0.078 | |
| | | | | | (0.076) | |
| Rainfall shock, age 19-22 | | | | | | 0.092 |
| | | | | | | (0.075) |
| Controls | yes | yes | yes | yes | yes | yes |
| Village Fixed Effects | yes | yes | yes | yes | yes | yes |
| Year of birth Fixed Effects | yes | yes | yes | yes | yes | yes |
| R2 | 0.142 | 0.141 | 0.139 | 0.156 | 0.160 | 0.162 |
| Observations | 683 | 678 | 673 | 656 | 638 | 616 |

Notes: OLS regression. Robust standard errors in parentheses, clustered at the village level. *** 1% , ** 5% , * 10% significance. Constant not displayed. Rainfall is the absolute value of rainfall deviation (in millimeters) from the rainfall historical mean in each cluster from 1981 to 2010 in the six months of the growing seasons (March, April, May and October, November, December). All the coefficients (standard errors) are multiplied by 100. Controls, as described in table 1, include dummies for mother and father highest level of education, bad house, a dummy indicating urban areas and dummies for the head of household ethnic group. Source: Kagera Health Development Survey, 1991-2010.

**Table 7: Rainfall shocks and bride price amount**

| *Dependent variable: Bride price amount (log)* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| Rainfall shock, age 17-18 | -0.239 | | | -0.170 | | | -0.152 | | |
| | (0.255) | | | (0.252) | | | (0.242) | | |
| Rainfall shock, age 16-18 | | -0.288 | | | -0.194 | | | -0.215 | |
| | | (0.234) | | | (0.220) | | | (0.210) | |
| Rainfall shock, age 15-18 | | | -0.407 | | | -0.301 | | | -0.363 |
| | | | (0.339) | | | (0.319) | | | (0.297) |
| Age at marriage | | | | 0.069 | 0.060 | 0.063 | 0.008 | -0.001 | 0.003 |
| | | | | (0.140) | (0.136) | (0.135) | (0.138) | (0.134) | (0.133) |
| Age at marriage sq. | | | | 0.000 | 0.000 | 0.000 | 0.002 | 0.002 | 0.002 |
| | | | | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) |
| Primary Educ. | | | | | | | 0.385** | 0.388** | 0.393** |
| | | | | | | | (0.166) | (0.167) | (0.163) |
| Secondary Educ. and above | | | | | | | 1.230*** | 1.225*** | 1.236*** |
| | | | | | | | (0.253) | (0.253) | (0.251) |
| Controls | yes | yes | yes | yes | Yes | yes | yes | yes | yes |
| Village Fixed Effects | yes | yes | yes | yes | Yes | yes | yes | yes | yes |
| Year of birth Fixed Effects | yes | yes | yes | yes | Yes | yes | yes | yes | yes |
| R2 | 0.229 | 0.232 | 0.231 | 0.265 | 0.267 | 0.267 | 0.308 | 0.309 | 0.310 |
| Observations | 443 | 442 | 441 | 443 | 442 | 441 | 441 | 440 | 439 |

Notes: OLS regression. Robust standard errors in parentheses, clustered at the village level. *** 1% , ** 5% , * 10% significance. Constant not displayed. Rainfall is the absolute value of rainfall deviation (in millimeters) from the rainfall historical mean in each cluster from 1981 to 2010 in the six months of the growing seasons (March, April, May and October, November, December). All the coefficients (standard errors) are multiplied by 100. Controls, as described in table 1, include dummies for mother and father highest level of education (no education, primary education and secondary/tertiary education), a dummy for respondents living in inadequate house, a dummy indicating urban areas and dummies for the head of household ethnic group. Source: Kagera Health Development Survey.

**Table 8: Parameter estimates**

| | *Estimate* | *Std. Err.* |
|---|---|---|
| Relative risk aversion b | 11.3115 | 0.1324 |
| $e_0$ | 0.9396 | 0.0067 |
| $e_1$ | -0.4347 | 0.0007 |
| $e_2$ | 0.0502 | 0.0001 |
| $e_3$ | -0.0020 | 0.000006 |
| $e_4$ | 0.000027 | 0.0000001 |
| $\sigma^2$ | 0.2113 | 0.0064 |
| $\mu$ | 14.3016 | 0.0353 |

# Appendix

**Table A1: Correlation between probability of marriage by 18 and women's socio economic outcomes and attitudes**

| | Outcomes | | | Attitudes | | | | |
|---|---|---|---|---|---|---|---|---|
| *Dependent variable* | *1 if secondary education and above* | *Age gap between spouses* | *First birth before or at 18* | *Little influence over the things - Agree* | *You are a failure - Agree* | *You are not good - Agree* | *Can improve your situation in life - Disagree* | *Low self-esteem - Index* |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Marriage before or in the year turning 18 | -0.062*** | 3.106*** | 0.551*** | 0.116** | 0.044 | 0.071 | 0.020 | 0.251*** |
| | (0.019) | (0.421) | (0.039) | (0.055) | (0.052) | (0.049) | (0.021) | (0.080) |
| R2 | 0.011 | 0.056 | 0.301 | 0.012 | 0.002 | 0.007 | 0.005 | 0.017 |
| Observations | 734 | 649 | 683 | 262 | 262 | 262 | 262 | 262 |

Notes: OLS regression. Robust standard errors in parentheses, clustered at the village level. *** 1% , ** 5% , * 10% significance. Constant not displayed. Sample of ever-married women. In column 3, the age gap is in absolute value. In column 4, the dependent variable is equal to 1 if the respondent totally agrees or somewhat agrees with the sentence "Many times you feel that you have little influence over the things that happen to you"; in column 5, the dependent variable is 1 if respondent totally agrees or somewhat agrees with "All in all you are inclined to feel that you are a failure"; in column 6, the dependent variable is 1 if respondent totally agrees or somewhat agrees with "At times you think you are no good at all"; in column 7, the dependent variable is 1 if the respondent totally disagrees or somewhat disagrees with "If you try hard you can improve your situation in life". The last column include the sum of all variables reported in columns 4-7. Source: Kagera Health Development Survey.

**Table A2: Probability of marriage by 18 and rainfall shocks in respondents' life cycle**

| *Dependent variable: 1 if married before or in the year turning 18* | Females | | | | | | Males | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
| Rainfall shock, age 15 | | | 0.017 | | | 0.035 | | | -0.002 | | | -0.007 |
| | | | (0.041) | | | (0.050) | | | (0.017) | | | (0.021) |
| Rainfall shock, age 16 | | 0.001 | 0.003 | | 0.004 | 0.001 | | -0.004 | -0.005 | | 0.007 | 0.010 |
| | | (0.038) | (0.039) | | (0.041) | (0.038) | | (0.014) | (0.015) | | (0.011) | (0.014) |
| Rainfall shock, age 17 | 0.044 | 0.041 | 0.045 | 0.042 | 0.062 | 0.081* | -0.026 | -0.027 | -0.028 | -0.028 | -0.021 | -0.028 |
| | (0.038) | (0.037) | (0.037) | (0.038) | (0.039) | (0.043) | (0.019) | (0.020) | (0.020) | (0.018) | (0.017) | (0.017) |
| Rainfall shock, age 18 | 0.077** | 0.086** | 0.092** | 0.077** | 0.113*** | 0.119*** | -0.009 | -0.010 | -0.010 | -0.011 | -0.014 | -0.013 |
| | (0.035) | (0.037) | (0.038) | (0.036) | (0.041) | (0.044) | (0.016) | (0.017) | (0.017) | (0.016) | (0.017) | (0.017) |
| Rainfall shock, age 19 | | | | -0.002 | -0.009 | 0.001 | | | | -0.013 | -0.015 | -0.020 |
| | | | | (0.028) | (0.032) | (0.036) | | | | (0.013) | (0.014) | (0.013) |
| Rainfall shock, age 20 | | | | | -0.043 | -0.028 | | | | | 0.019 | 0.015 |
| | | | | | (0.044) | (0.049) | | | | | (0.019) | (0.017) |
| Rainfall shock, age 21 | | | | | | -0.032 | | | | | | -0.005 |
| | | | | | | (0.036) | | | | | | (0.020) |
| Rainfall shock, age 22 | | | | | | -0.030 | | | | | | -0.019 |
| | | | | | | (0.036) | | | | | | (0.021) |
| Controls | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| Village FE | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| Year of birth FE | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| R2 | 0.155 | 0.156 | 0.153 | 0.154 | 0.154 | 0.161 | 0.195 | 0.198 | 0.200 | 0.199 | 0.205 | 0.199 |
| Observations | 737 | 732 | 727 | 720 | 703 | 662 | 513 | 503 | 495 | 505 | 490 | 475 |

Notes: OLS regression. Robust standard errors in parentheses, clustered at the village level. *** 1% , ** 5% , * 10% significance. Constant not displayed. Rainfall is the absolute value of rainfall deviation (in millimeters) from the rainfall historical mean in each cluster from 1981 to 2010 in the six months of the growing seasons (March, April, May and October, November, December). Controls, as described in table 1, include dummies for mother and father highest level of education (no education, primary education and secondary/tertiary education), a dummy for respondents' living in inadequate house, a dummy indicating urban areas and dummies for the head of household ethnic group. All the coefficients (standard errors) are multiplied by 100. Source: Kagera Health Development Survey.

**Table A3: Probability of marriage by age 19-23, sample of females**

| *Dependent variable:* | *1 if married by age 19* | | | *1 if married by age 20* | | | *1 if married by age 21* | | | *1 if married by age 22* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
| Rainfall shock, age 17-18 | 0.125* | | | 0.175** | | | 0.098 | | | 0.064 | | |
| | (0.075) | | | (0.069) | | | (0.067) | | | (0.060) | | |
| Rainfall shock, age 16-18 | | 0.112 | | | 0.159** | | | 0.085 | | | 0.032 | |
| | | (0.073) | | | (0.080) | | | (0.075) | | | (0.068) | |
| Rainfall shock, age 15-18 | | | 0.150* | | | 0.211** | | | 0.179** | | | 0.080 |
| | | | (0.087) | | | (0.100) | | | (0.090) | | | (0.072) |
| Rainfall shock, age 19 | -0.031 | -0.037 | -0.044 | | | | | | | | | |
| | (0.037) | (0.037) | (0.037) | | | | | | | | | |
| Rainfall shock, age 19-20 | | | | -0.065 | -0.061 | -0.054 | | | | | | |
| | | | | (0.066) | (0.074) | (0.066) | | | | | | |
| Rainfall shock, age 19-21 | | | | | | | 0.071 | 0.080 | 0.070 | | | |
| | | | | | | | (0.088) | (0.089) | (0.088) | | | |
| Rainfall shock, age 19-22 | | | | | | | | | | 0.048 | 0.057 | 0.057 |
| | | | | | | | | | | (0.073) | (0.072) | (0.072) |
| Controls | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| Village FE | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| Year of birth FE | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| R2 | 0.147 | 0.144 | 0.145 | 0.169 | 0.163 | 0.164 | 0.144 | 0.140 | 0.144 | 0.158 | 0.151 | 0.152 |
| Number of observations | 720 | 715 | 710 | 708 | 703 | 698 | 692 | 687 | 682 | 672 | 667 | 662 |

Notes: OLS regression. Sample of females. Robust standard errors in parentheses, clustered at the village level. *** 1% , ** 5% , * 10% significance. Constant not displayed. Rainfall is the absolute value of rainfall deviation (in millimeters) from the rainfall historical mean in each cluster from 1981 to 2010 in the six months of the growing seasons (March, April, May and October, November, December). Controls, as described in table 1, include dummies for mother and father highest level of education (no education, primary education and secondary/tertiary education), a dummy for respondents living in a bad house, a dummy indicating urban areas and dummies for the head of household ethnic group. All the coefficients (standard errors) are multiplied by 100. Source: Kagera Health Development Survey.

**Table A4: Probability of marriage by age 19-23, sample of males**

| *Dependent variable:* | *1 if married by age 19* | | | *1 if married by age 20* | | | *1 if married by age 21* | | | *1 if married by age 22* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
| Rainfall shock, age 17-18 | -0.071* | | | -0.048 | | | -0.056 | | | 0.030 | | |
| | (0.040) | | | (0.061) | | | (0.060) | | | (0.078) | | |
| Rainfall shock, age 16-18 | | -0.087* | | | -0.049 | | | -0.061 | | | 0.067 | |
| | | (0.050) | | | (0.061) | | | (0.059) | | | (0.089) | |
| Rainfall shock, age 15-18 | | | -0.075 | | | -0.129* | | | -0.142** | | | 0.094 |
| | | | (0.062) | | | (0.077) | | | (0.070) | | | (0.101) |
| Rainfall shock, age 19 | -0.013 | -0.009 | -0.008 | | | | | | | | | |
| | (0.021) | (0.020) | (0.021) | | | | | | | | | |
| Rainfall shock, age 19-20 | | | | 0.036 | 0.041 | 0.034 | | | | | | |
| | | | | (0.052) | (0.052) | (0.053) | | | | | | |
| Rainfall shock, age 19-21 | | | | | | | 0.082 | 0.095 | 0.082 | | | |
| | | | | | | | (0.077) | (0.076) | (0.076) | | | |
| Rainfall shock, age 19-22 | | | | | | | | | | 0.088 | 0.092 | 0.099 |
| | | | | | | | | | | (0.106) | (0.108) | (0.111) |
| Controls | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| Village FE | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| Year of birth FE | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| R2 | 0.147 | 0.144 | 0.145 | 0.169 | 0.163 | 0.164 | 0.144 | 0.140 | 0.144 | 0.158 | 0.151 | 0.152 |
| Number of observations | 720 | 715 | 710 | 708 | 703 | 698 | 692 | 687 | 682 | 672 | 667 | 662 |

Notes: OLS regression. Sample of males. Robust standard errors in parentheses, clustered at the village level. *** 1% , ** 5% , * 10% significance. Constant not displayed. Rainfall is the absolute value of rainfall deviation (in millimeters) from the rainfall historical mean in each cluster from 1981 to 2010 in the six months of the growing seasons (March, April, May and October, November, December). Controls, as described in table 1, include dummies for mother and father highest level of education (no education, primary education and secondary/tertiary education), a dummy for respondents living in inadequate house, a dummy indicating urban areas and dummies for the head of household ethnic group. Source: All the coefficients (standard errors) are multiplied by 100. Source: Kagera Health Development Survey.

**Table A5: Probability of marriage in the year turning 16 and 17**

| *Dependent variable:* | *1 if married in the year turning 16 or before* | *1 if married in the year turning 17 or before* | *1 if married in the year turning 16 or before* | *1 if married in the year turning 17 or before* |
|---|---|---|---|---|
| | **Females** | | **Males** | |
| | (1) | (2) | (3) | (4) |
| Rainfall shock, age 17-18 | -0.025 | | -0.011 | |
| | (0.040) | | (0.016) | |
| Rainfall shock, age 18-19 | | 0.063 | | -0.019 |
| | | (0.039) | | (0.017) |
| Controls | yes | yes | yes | yes |
| Village FE | yes | yes | yes | yes |
| Year of birth FE | yes | yes | yes | yes |
| R2 | 0.147 | 0.149 | 0.151 | 0.167 |
| Observations | 737 | 720 | 513 | 505 |

Notes: OLS regression. Robust standard errors in parentheses, clustered at the village level. *** 1% , ** 5% , * 10% significance. Constant not displayed. Rainfall is the absolute value of rainfall deviation (in millimeters) from the rainfall historical mean in each cluster from 1981 to 2010 in the six months of the growing seasons (March, April, May and October, November, December). Controls, as described in table 1, include dummies for mother and father highest level of education (no education, primary education and secondary/tertiary education), a dummy for respondents living in inadequate house, a dummy indicating urban areas and dummies for the head of household ethnic group. All the coefficients (standard errors) are multiplied by 100. Source: Kagera Health Development Survey.

**Table A6: Wild bootstrapped p-values for main coefficients**

| Table | Column | Coefficient | P-value |
|---|---|---|---|
| Table 3 | 1 | Rainfall shock, age 17-18 | 0.076 |
| | 2 | Rainfall shock, age 16-18 | <0.01 |
| | 3 | Rainfall shock, age 15-18 | <0.01 |
| | 4 | Rainfall shock, age 17-18 | 0.036 |
| | 5 | Rainfall shock, age 16-18 | 0.020 |
| | 6 | Rainfall shock, age 15-18 | <0.01 |
| Table 5 | 1 | Rainfall shock, age 17 *Neighbors' bride prices, age 17 | 0.328 |
| | 1 | Rainfall shock, age 18 *Neighbors' bride prices, age 18 | 0.256 |
| | 2 | Rainfall shock, age 16 *Neighbors' bride prices, age 16 | 0.004 |
| | 2 | Rainfall shock, age 17 *Neighbors' bride prices, age 17 | 0.148 |
| | 2 | Rainfall shock, age 18 *Neighbors' bride prices, age 18 | 0.224 |
| | 3 | Rainfall shock, age 15 *Neighbors' bride prices, age 15 | 0.308 |
| | 3 | Rainfall shock, age 16 *Neighbors' bride prices, age 16 | 0.552 |
| | 3 | Rainfall shock, age 17 *Neighbors' bride prices, age 17 | 0.348 |
| | 3 | Rainfall shock, age 18 *Neighbors' bride prices, age 18 | 0.068 |
| Table 6 | 1 | Rainfall shock, age 17-18 | 0.180 |
| | 2 | Rainfall shock, age 16-18 | 0.112 |
| | 3 | Rainfall shock, age 15-18 | 0.124 |
| | 4 | Rainfall shock, age 17-18 | 0.196 |
| | 5 | Rainfall shock, age 16-18 | 0.104 |
| | 6 | Rainfall shock, age 15-18 | 0.036 |

Notes: The table reports the p-values of a t-test in which the null is the equality of a coefficient to zero. They are obtained by following the wild bootstrap procedure (Cameron, Gelbach and Miller, 2008), with clustering at the level of the ten rainfall grids, i.e. at the level at which the rainfall is measured, with 500 draws.