Child Marriage as Informal Insurance: Empirical Evidence and Policy Simulations

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Abstract

This paper investigates the relationship between child marriage and economic incentives in a setting where the bride price - a transfer from the groom to the bride's parents at marriage - is customary. First, we develop a dynamic model in which households are exposed to income volatility and have no access to credit markets. If a daughter marries, her household obtains a bride price. In this framework, girls may have a higher probability of marrying early when their parents have a higher marginal utility of consumption because of adverse income shocks. Second, we measure the responsiveness of child marriage to income fluctuations 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. Third, 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 enforcing child marriage bans can have lasting effects on the timing of marriage even after a woman has exceeded the minimal age of marriage. The utility cost to parents of such enforcement is relatively small. Cash transfers, both conditional on avoiding child marriage and unconditional, can reduce early marriages, especially when they target low-income households.

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1 Introduction

Child marriage is still a common practice in many countries, especially among girls. Worldwide, 700 million women alive today married before turning 18. This phenomenon is especially pronounced in Sub-Saharan Africa and South Asia, where the prevalence of child marriage is 56% and 42%, respectively (UNICEF, 2019). The relationship between female early marriage and poor physical and socioeconomic outcomes is well established in the literature. Child marriage is associated with lower 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; Chari et al., 2017).[1]

Despite this evidence, little research has so far examined potential factors driving to the persistence of child marriage and potential effective policies to reduce its prevalence. This paper explores the role of income fluctuations in influencing child marriage and how economic policies could curb its persistence. It first estimates the relationship between child marriage and rainfall shocks, our proxy for income volatility, in a setting where the bride price – a transfer from the groom to the family of the bride at the time of marriage – is customary. It then uses these estimates to inform a dynamic discrete choice model of child marriage and to perform counterfactual simulations to assess how economic policies, like minimal age of marriage enforcement and cash transfer programs, can reduce the prevalence of child marriage.

We start by theoretically exploring the relationship between the probability of child marriage, defined as a formal or informal union in which a girl married before or at the age of 18 (UNICEF, 2014) and adverse income shocks, in a context where bride price payments are prevalent. We develop a 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 her household's budget through her 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 raises the

[1]Based on these findings, international organizations have called for "urgent action", arguing that the eradication of child marriage is a necessary step towards improving female human capital accumulation, empowerment and autonomy around the world (UNFPA, 2012; UNICEF, 2014). The elimination of harmful practices is also part of the Sustainable Development Goals 2015-2030, a collection of 17 global goals set by the United Nations General Assembly, reflecting the priorities to reduce poverty around the world.

hazard of marriage in the same period, as long as the bride price exceeds the daughter's one-period contribution to home production.

We test this theoretical prediction using a survey dataset from a region 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, which provides data oon rainfall across several years (1981-2010) and 10 terrestrial grids in the Kagera region. In particular, we exploit exogenous variation in rainfall precipitation to estimate the causal effects of rainfall shocks, our proxy for income shocks, on the age of marriage. We define negative rainfall shocks as the absolute value of yearly rainfall deviation from the historical mean in each village in our sample from 1981 to 2010 in the six months of the growing seasons in Tanzania. To study the relationship between rainfall shocks and the timing of marriage, we match each woman to the area in which she grew up, and reconstruct the history of rainfall shocks that she experienced over time. This procedure allows us to estimate whether rainfall shocks experienced at each age during youth have a short-term impact on the probability of marriage by age 18, holding constant any shock at the aggregate level of the Kagera region.

Our first result shows indeed that negative rainfall shocks are associated with sizable declines in household consumption. Second, in line with the theoretical model, we find that girls who were hit by a negative rainfall shock in their teenage years have a higher probability of being married by the age of 18. In terms of magnitude, one standard deviation increase in our measure of rainfall shocks averaged during teenage years (8-18) increases a girl's probability to be married by age 18 by 10.7 percentage points. This effect corresponds to a 36% increase in child marriage probability compared to the mean and it is robust to the inclusion of various socio-demographic controls. On the contrary, rainfall shocks are not associated with men's marriage timing. Third, we exploit variation in bride price amount and household's composition to analyse heterogeneous effects of rainfall shocks on early marriage. By using data on bride price amounts across villages, we show that the relationship between female child marriage and negative rainfall shocks is stronger in villages where bride price payments are typically higher. Regarding a potential differential impact of income shocks by household composition, we find that the probability of early marriage, in the presence of an adverse shock, is lower for girls with a higher number of sisters within the household. Finally, possibly because the rainfall shocks affect a relatively small share of the marriage market in each period, we find that they do not affect the level of bride price paid at the time of marriage.

To assess the role of bride price as a consumption-smoothing mechanism and to perform policy simulations, we estimate the parameters of our dynamic model by indirect inference, targeting the responsiveness of child marriage to shocks, the marriage-age profile, and the empirical distribution of consumption in the data. We find that families generally prefer to delay the marriage of their daughters, but that the inability to borrow or save leads to an age of marriage that is often lower than what is preferred from the household's preferences. In this model, a bride price is also important for marriage to occur, because daughters are productive in their parents' home.

We use the model to perform two counterfactual exercises. Enforcing child marriage bans can have lasting effects on the age of marriage even after they are no longer binding, because the marriage rate does not immediately increase once the girl is eligible to marry. Nevertheless, because child marriage is a tool to cope with income volatility, a child marriage ban may be unpopular without compensating policies. Other programs, like conditional cash transfers and even unconditional cash transfers, can also be effective at reducing child marriage, especially when they target low-income households.

Our paper fits into four main strands of the literature. First, the paper is related to the recent literature looking at the effect of income shocks on marriage decisions. Hoogeveen, Van der Klaauw and Van Lomwel (2011) investigate the effect of economic conditions on marriage's choices among a small sample of Zimbabwean smallholder farmers in rural areas. They find that the marriage rate for daughters is higher when households experience changes in their livestock, but not when aggregate rainfall is low. Relative to this paper, we focus on the effect of exogenous rainfall shocks and we have the advantage of exploiting a larger sample that allows us to identify the elasticity of child marriage to rainfall shocks, which informs then our structural estimates. Corno, Hildebrandt and Voena (2020) study the impact of aggregate rainfall shocks on child marriage in Sub-Saharan Africa and India and show an opposite effect of the shocks 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 is explained by differences in the direction of traditional marriage payments in each region, with bride price being prevalent in Africa and dowry in India. Compared to this study, we are able to estimate our model by relying on one of the very few surveys that elicits information on bride price amount, the Kagera Health and Development Survey. Exploiting the bride price data, we can estimate a dynamic discrete choice model of age of marriage, and use it to conduct counterfactual simulations of different policies aimed at reducing child marriage. Moreover, by including year of birth fixed effects, our empirical analysis allows us to control for aggregate shocks at the regional level (Kagera), rather than at the country level or continent level as in Corno, Hildebrandt and Voena (2020), and hence to examine the impact of shocks that affect smaller geographic areas (grid). This difference may explain why we do not detect any decline in brideprice associated with rainfall shocks. By focusing on one single region, whose main ethnic group has well-established patrilocal exogamy and bride price practices Cory and Hartnoll (2005), the estimates are less likely to be confounded by the vast heterogeneity of practices that is present throughout Sub-Saharan Africa.[2]

Second, the paper contributes to the large economic literature that investigates the coping mechanisms used by poor households to deal with income risk. Despite imperfect markets for formal insurance, rural households seem well-equipped to smooth consumption to face short-term, idiosyncratic income shocks, often through informal insurance arrangements, such as transfers in family networks, storage of crops, diversification of farmers' landholdings (Rosenzweig, 1988; Rosenzweig and Stark, 1989; Townsend, 1994; Fafchamps and Lund, 2003; De Weerdt and Dercon, 2006; Angelucci, De Giorgi and Rasul, 2018). In this paper, using detailed data on bride price payment, we confirm the hypothesis that in societies where bride price is customary, child marriage can be another relevant strategy to smooth consumption, thus perpetuating the risk of poverty.

Third, our work is related to the broad literature investigating the role of cultural and social norms on economic behavior. Previous studies examined the role of cultural values and beliefs such as trust, family ties, and gender norms on economic outcomes (Platteau, 2000; Fernandez,

[2]For example, using a novel dataset from Senegal, Hotte and Lambert (2020) document that in such a context, bride price payments are distributed to the bride's extended family, and hence are less likely to provide significant relief from income shocks to the bride's parents. Indeed, they find that exposure to negative rainfall shocks raises the age of marriage.

Fogli and Olivetti, 2004; Guiso, Sapienza and Zingales, 2006; Fernandez and Fogli, 2009; Tabellini, 2010; Nunn and Wantchekon, 2011; Corno, La Ferrara and Voena, 2020). A growing part of this literature explored the influence of marriage practices (e.g., polygyny, patrilocal norms, dowry and bride price) on development (see, among others, Jacoby (1995); Tertilt (2005); Anderson (2007); Anderson and Bidner (2015); Ashraf et al. (2020)). The latter remains a particularly worthwhile yet under-explored topic to study, given that marriage practices are likely to have a profound effect on people's life and on their economic circumstances (Botticini, 1999). Compared to these previous works, we examine the role of the bride price payment on child marriage through the lenses of a structural model that allows for policy experiments.

Finally, our paper also contributes to the literature showing that children's outcomes, and particularly girls' outcomes, in developing countries are sensitive to income fluctuations (Foster, 1995). Björkman-Nyqvist (2013) find that a negative income shock has an adverse effect on the test scores of female students. The results imply that households respond to income shocks by varying the amount of schooling and resources provided to daughters.

The remainder of the paper is organized as follows. In section 2, we describe the tradition of marriage payments, 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 descriptive statistics. In section 5, we describe the empirical strategy, in section 6 we report our main results and robustness checks. Section 7 estimates the structural models and shows the results of the counterfactual policy simulations and section 8 concludes.

2 Child marriages and bride price payment

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. The 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, a dowry payment involves a transfer from the bride to the family of the groom upon the marriage.[3]

[3] For studies investigating the historical occurrence of bride price versus dowry see Boserup (1970); Grossbard (1978); Becker (1981); Giuliano (2014); Goody and Tambiah (1973); 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 ethnic groups listed in the George Peter Murdock's (1967) *Ethnographic Atlas* have dowry payments, whereas about two-thirds follow a norm of bride price payment.[4] However, dowry payments have been studied more extensively in the economics literature, possibly because they mainly occurred in Europe and Asia, where more than 70 percent of the world's population resides. Although the custom of dowry has disappeared in most of the western regions, it remains widespread in South Asia. Bride price payments have as well an ancient tradition and are common across sub-Saharan Africa. In the southern regions, it is known as *lobola* and in East Africa as *mahari*. Besides Africa, bride price custom is widespread in some regions of South and East Asia, such as Indonesia (Maitra, 2007).

Depending on cultural traditions, bride prices can be paid either in cash, in-kind or a combination of both. In both cases, they usually represent large transfers of money across households at the time of marriage and as such we believe they have important consequences on households' economic decisions.

The debate over the adverse consequences of the bride price custom is currently lively in Africa (see, among others, Makoye 2013 and Mtui 2013). It has been argued that this practice increases the incentive for parents to "sell off" their daughters to a groom in order to receive a bride price and has contributed to child marriages, so encouraging forced and early marriages. In a recent interview of the Thompson Reuters Foundation conducted in a village in Bagamoyo, Tanzania, a 15-year-old bride said "*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 wishes who wanted to get a payment to cover his financial problem*" (Makoye, 2013). Furthermore, bride price custom also affects a women's right to divorce because men can demand from the bride's parents the return of the payment: a high bride-price serves as a commitment device aimed at minimizing the risk of marriage breakup (The Guardian, 2015).

Bride price is widespread in our area of focus, the Kagera region in Tanzania. According to *Ethnographic Atlas* (Müller et al., 1999), the Haya people, the main ethnic group in Kagera, have

[4]The Atlas provides historical information on transfers made at marriage, either bride price or dowry, by ethnic groups all over the world (Murdock, 1967).

traditionally practiced patrilineal and patrilocal exogamy. This characterization is consistent with the one that arises from the treatise *Customary Law of the Haya Tribe* (Cory and Hartnoll, 2005), which states that "A marriage between two members of the same clan is prohibited". Cory and Hartnoll (2005) highlight that the bride price being paid in full by the time of marriage is the "usual arrangement" (p.62) among the Haya people, suggesting that the bride price could provide a relatively short-term source of relief to families struck by negative shocks.

An important connection to mention is the one between child marriage and women's education. While child marriage may reduce women's education opportunities, expanding such opportunities may in turn help combat child marriage. Women's education may also lead to higher bride price payments, encouraging parents to educate their daughters (Ashraf et al., 2020). Unfortunately, our context and time period are not the appropriate ones to study these important questions. In particular, education levels in our sample are relatively low even compared to ages of marriage: 91% of our sample reports never attending secondary school. The remaining 9% reports some secondary schooling, but only 5% reports having to complete it. Among women who marry by age 18, 95% reports never attending secondary school. This data leads us to consider educational attainment as largely predetermined by the time the young women in our sample are on the margin of entering marriage, even among those who marry early.

3 The model

In this section, we develop a dynamic discrete-choice model with incomplete markets in which households are exposed to 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.

3.1 Setup

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

$14 < A < T$.[5] Period 1 is the time of birth of the daughter, and hence we can refer to periods and a woman's 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 $M_a(s^a) = 1$.

The parents solve the following problem:

$$
\begin{aligned}
max_{c\geq 0, m\in\{0,1\}} \quad & \sum_{a=14}^{T} \delta^{a-14} E\left[u\left(c_a(s^a)\right)\right] + m_a(s^a)\cdot \xi_a \\
s.t. \quad & \frac{c_a(s^a)}{1 + e\cdot(1 - M_a(s^a))} \leq y_a(s_a) + BP_a \cdot m_a(s^a) \\
& M_{13} = 0.
\end{aligned}
$$

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

$$
\begin{aligned}
&\text{if } M_{a-1}(s^{a-1}) = 1, \text{ then } m_a(s^a) = 0 \\
&\text{if } M_{a-1}(s^{a-1}) = 0 \text{ and } m_a(s^a) = 0, \text{ then } M_a(s^a) = 0 \\
&\text{if } m_a(s^a) = 1, \text{ then } M_a(s^a) = 1, ..., M_A(s^A) = 1.
\end{aligned}
$$

The parameter e captures the proportional contribution provided or the cost imposed by a daughter on the household consumption when she is living with her parents: a negative e implies that the daughter is costly to support, while a positive e captures any contribution of the daughter to consumption through home production. Last, the age specific-parameter ξ_a represents the utility gain or cost of having the daughter marry at age a.

In this simple framework, the daughter acts as an indivisible asset and the timing of her marriage is an optimal stopping problem. The demand for brides by potential husbands is unaffected by

[5] We set the initial period to age 14, when considerations on child marriage are less relevant. For an analysis of child labor in the KHDS data, see Beegle, Dehejia and Gatti (2006).

$y_a(s_a)$, which is idiosyncratic to the bride's family. The daughter can get married in any period as long as the parents choose so.

3.2 Solving the model: income shocks and timing of marriage

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 as long as her contribution to the household budget in one period is smaller than the bride price.

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:

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

This optimal-stopping problem can be solved backwards. 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:

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

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

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

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:

$$u(y_a + BP_a) + \delta E[V_{a+1}^1] > u(y_a \cdot (1 + e)) + \delta E[V_{a+1}^0].$$

The above condition justifies our main empirical test, as the model predicts that a drop in income y_a increases the hazard of marriage at age a when $ey_a < BP_a$, and viceversa. That is, when $ey_a < BP_a$, the hazard of marriage is monotonically decreasing in the income realization y_a:

$$P[m_a = 1 | M_a = 0] = P\left[u(y_a + BP_a) - u(y_a \cdot (1 + e)) > \delta \left(E[V_{a+1}^0] - E[V_{a+1}^1]\right)\right].$$

This is because, in the absence of credit markets, the option value $\delta \left(E[V_{a+1}^0] - E[V_{a+1}^1]\right)$ does not depend on y_a and the strict concavity of the utility function ensures that $\frac{\partial [u(y_a + BP_a) - u(y_a \cdot (1+e))]}{\partial y_a} < 0$ whenever $BP_a > ey_a$, and viceversa.

In what follows, we measure the relationship between income shocks at given ages (proxies for y_a) using rainfall shocks as an exogenous source of variation in income, on the probability of marriage in those ages. We will then structurally estimate the above model to perform counterfactual policy simulations.

This setup relies on the assumption that we can identify shocks to households that do not affect the level of the bride price paid, hence that shocks have negligible general equilibrium effects ($\frac{\partial BP_a}{\partial y_a} = 0$). Aggregate rainfall realizations affect multiple households at the same time and hence have the potential to influence the equilibrium bride price payments. In particular, a price effect may attenuate the response of child marriage (Corno, Hildebrandt and Voena, 2020). In what follows, we will also test whether the rainfall shocks are over large enough areas to generate price effects.

4 Data and Descriptive Statistics

In this section, we describe the main sources of data used in the empirical analysis and in the structural estimation.

4.1 Marriage and bride price data

Our first source of data is 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 about 30% 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 elicits information for the first time in 1991 among more than 800 households from nearly 50 communities in all five districts of Kagera. The primary objective of the first survey round was to estimate the economic impact of the death of prime-age adults on surviving household members. The same sample of individuals has been interviewed 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.[6]

Several features make this dataset particularly appropriate for studying the correlation between bride price payments and marital outcomes. First, the last two waves of the survey (2004 and 2010) elicit detailed retrospective information on marriage, including the year of marriage, the crucial variable for our analysis, as well as all the cash and in-kind transfer amounts from the groom's family to the bride's family at the time of marriage. To the best of our knowledge, the KHDS is one of the very few surveys that elicits information on bride price amounts in Sub-Saharan Africa.[7] Second, the data include information on each respondent's current village of residence but also information on respondent's migration from her village of birth. The latter

[6]For additional information on the KHDS Beegle, Dehejia and Gatti (2006); De Weerdt et al. (2012).

[7]Data on bride price payments are mainly collected through *ad hoc* household surveys on specific projects. For example, Mbaye and Wagner (2017) used data on marriage payments in Senegal, collected as part of a program evaluation of a rural electrification initiative implemented by the UNDP, to test the correlation between bride price and fertility decisions. Lambert, van de Walle and Villar (2018) collected bride price data in Senegal to analyze marital trajectories and women's well-being. Ashraf et al. (2020) gathered bride price data in some peri-urban areas around Lusaka, the capital of Zambia.

information allows us to track where the individual lived as a child and as a youth beyond her current residential location. We can therefore rely on our measure of weather shocks, computed at the grid level during a respondent's life cycle, even if she migrated at the time of marriage. This information is particularly relevant for our purpose given that, in Kagera, patrilocal exogamy is the practice: the bride moves to the groom's family at the time of marriage. Having data on where the bride was living before marriage, allows to measure shocks that affected the family of the bride but, potentially, not the one of the groom or, more generally, the marriage market.[8] Finally, the survey includes a siblings' roster, so eliciting information on the household's composition of each respondent. We can therefore test how the probability of early marriage, in response to adverse rainfall shocks, changes depending on the number of brothers and sisters each respondent has.

Our main outcome variable - the year of marriage - has been collected retrospectively: each married respondent is asked to recall the year when they were first married. In 2004, this information was elicited during the survey, in 2010 instead the research team primarily used phone interviews.[9]

The age of marriage has been computed by taking the difference between the year of marriage and the year of birth, given that the survey does not elicit information on the month of marriage. Thus, unfortunately, some measurement error in the age of marriage is to be expected. For example, individuals that are recorded to be married at the age of 18 could have been married instead at the age of 17, if the month of wedding is before the month of birth in the calendar year. Also, note that women may face difficulty recollecting their age of marriage or misreport their age and year of birth. If such errors are uncorrelated with rainfall shocks, they are likely to reduce the precision of our estimates. While no studies have so far examined measurement errors in age and

[8]More precisely, to obtain the cluster of residence in different years of the respondent's life cycle, we exploit information on i) baseline cluster of residence in 1991-1994; ii) the number of migrations and the year of migration from the cluster of birth to another cluster; iii) the year of birth. In particular, we construct the cluster of residence during youth by using the cluster of residence elicited in 1991-94 if the individual never moved (63.5% of the sample); by using information on the year of migration if the respondent moved once and assigned the 1991-94 cluster of residence in the years before the date of migration but the 2010 current cluster of residence in the years after migration (26.15% of the sample); if the individual moved more than once we record his/her position before the first migration and after the last migration again combining baseline cluster of residence in 1991-1994 and the cluster of residence in 2010 (6.64% of the sample). Unfortunately, in a few cases, we had missing information on the year of migration and we can therefore only record an individual's 2010 cluster of residence (3.71% of the sample).

[9]For additional information on the construction of the wedding data and for download the dataset see https://www.uantwerpen.be/en/staff/joachim-deweerdt/public-data-sets/khds/

date in the KHDS, we refer to Pullum (2006), who examines such biases in the Demographic and Health Surveys, limiting concerns about the effect of measurement error. In particular, we find no evidence of age heaping in the distribution of ages at marriage (see Figure 1), a commonly used diagnostic tool.

Given that the age of marriage does not change across survey rounds, in our empirical analysis we keep only the latest wave in which each individual has been interviewed. We therefore work with a cross-sectional dataset where the majority of the respondents (96.79%) have been interviewed for the last time in 2010 and a small portion (3.21%) have been surveyed for the last time in the 2004 wave.

Our final sample with non-missing information on the age of marriage and on the variable capturing weather shocks (described in the next section) includes 1,246 married individuals (735 women, 511 men), aged 18-46, born between 1965 and 1991. In Appendix A, we provide a detailed description of potential variation in the sample sizes used in the empirical analysis.

[Insert Figure 1]

In Tanzania, the legal minimum age of marriage for boys is 18, while girls are legally eligible to marry at 15. However, either gender 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 the dissolution of marital union (USAID, 2013). In our data, we defined child marriage as a union where at least one member got married at the age of 18 or younger. 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. As shown in Figure 1, a sizable portion of women marries during their teenage years, while typically fewer men do so. In particular, approximately 4% of the respondents got married in the year they turned 15 (6% among women and 0.1% among men) and about 20% of the sample reported an age of marriage below or equal to 18 years (4% among men and 30% among women).

[Insert Table 1]

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.[10] In the KHDS 2010, data on bride price amount have been collected from the groom's side.[11] The bride price is paid both in formal and informal marriage (Kudo, 2015).

As shown in Panel A of Table 1 (column 1), a large share of married individuals (81%) reported that a bride price was paid at the time of marriage. The average amount of bride price payment in our sample is 115,683 Tanzanian Shillings (about 50 USD).[12] By comparison, the median annual household expenditure on durable goods in our KHDS sample is equal to 88,000 Tanzanian Shillings and the median expenditure on medication and other health-related expenses is 11,000 Tanzanian Shillings. In the empirical analysis, 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). In Panel B, of Table 1 (column 1), we report the type of bride price payment: we note that the highest fraction of bride price is paid in cash (62%), followed by in-kind and in livestock. The principal receivers of the transfer, as expected, are bride's parents (57%) (Panel C, Table 1). When splitting the sample between respondents who got married before or in the year turning 18 (column 2, Table 1) and after 18 years (column 3, Table 1), we note that the bride price payment is higher for individuals who got married at an older age, suggesting that maximizing bride price received may not be a crucial reason behind child marriage.

In Appendix Figure A1, we report variation in bride price amount across the 51 cluster in our sample. The horizontal line is the average bride price equal to 115,683.46 Tanzanian Shillings. We observe considerable variation above and below the mean for each cluster.

Finally, to check variation in bride price payments by ethnicity, we matched the 41 ethnic

[10] In our data, in-kind payments include clothes, blankets, banana, beers, raw meat, sugar, cooking oil, milk, tea, hand tools, and kerosene.

[11] The exact questions included in the survey was: "Was there any item given to the parents of "BRIDE NAME" and how much was it worth?"; the same question was then asked to other family members.

[12] Respondents were asked to report the corresponding cash value in Tanzanian Shilling of bride prices paid in-kind or in livestock. A median amount of 115,683.46 Tanzanian Shillings in 2022 real terms corresponds to 49.82 USD in 2022, approximately 20.7% of the per capita GDP of Kagera, which was 559,070 Shillings in 2011 (`http://tanzania.opendataforafrica.org/TZSOCECD2016/social-economics-of-tanzania-2016?region=1000190-kagera&indicator=1002980-gdp-per-capita-at-current-prices-tshs`, last accessed April 11th, 2022).

groups of the household head listed in the KHDS with the *Ethnographic Atlas* (1967) by George Peter Murdock (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. (2020) and Corno, Hildebrandt and Voena (2020), we cannot exploit variation in ethnic origin to isolate the effect of bride price on outcomes. Thus, we will construct a structural model to disentangle the role of bride price from that of the economic costs associated with raising a daughter and the household's preferences for different ages of marriage.

[Insert Table 2]

Table 2 shows summary statistics for the main variables of interest, separately by gender. Panel A reports the mean and standard deviation of the variables related to the marriage markets, previously described. Panel B shows socio-demographic characteristics of the respondents and Panel C reports statistics related to rainfall shocks. Except for the age of marriage (20.37 years for women and 24.25 for men), we did not find striking differences in the characteristics of females and males in our sample. In Appendix Table A1 we report the same descriptive statistics for the entire sample. Only 24% of the respondents live in urban areas. Approximately 91% (87%) of women have a mother (father) with primary education, while only 5% (10%) of them report a mother (father) with secondary education or higher. About 40% of the respondents live in inadequate houses, with floors, walls and roofs made of mud, bamboo tree or earth.

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 working in agriculture 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 activities 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 and variations in rainfall may result in large fluctuations in income and consumption for Tanzanian households. In Kagera, *official* natural hazards may include both drought and flooding. Indeed, Kagera region is crossed by the Kagera River, the largest single inflow into the Lake Victoria, contributing approximately to 6.4 billion cubic metres of water a year (about 28 percent of the total lake's outflow).[13] We therefore use estimates on rainfall precipitations as a source of exogenous variation for income shocks.[14]

Rainfall data come from the Modern-Era Retrospective analysis for Research and Applications (MERRA) database at the NASA Langley Research Center, USA. 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) from 1981 to 2010 aggregated into 10 grids that are $1/2°$ in latitudes $*$ $2/3°$ in longitude, approximately corresponding to areas of $55*75$ km at the equator. Daily precipitation across grids are linked to our 51 villages (or clusters) through GPS coordinates.

[Insert Figure 2]

We report the geographic location of Kagera and villages across grids in our sample in Figure 2. Note that an offset of 0-2 kilometers for urban areas and 0-5 kilometers for rural areas was applied to the GPS location of clusters. This is a possible reason why some clusters seem to be located outside Kagera.[15]

We construct our measure of rainfall shock as follows. We first compute the total sum of daily rainfall (in millimeters) by year for each cluster and the historical mean level of annual precipitations during the growing seasons in Kagera (March, April, 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 grow and therefore for households' consumption

[13]In Kagera, river flood hazard is classified as "High" based on modeled flood information currently available at the ThinkHazard website, a think tank constructed by the World Bank and the Global Facility for Disaster Reduction and Recovery (GFDRR) that provides a general view of the hazards, for a given location (see https://thinkhazard.org/en/report/115004-tanzania-kagera/FL).

[14]The use of weather variations as a proxy for income shocks in developing countries is widespread in the literature. See Miguel, Satyanath and Sergenti (2004), Björkman-Nyqvist (2013), Dustmann and Speciale (2017) among others.

[15]KHDS household GPS coordinates for 1991-94, 2004 and 2010 can be downloaded here https://www.uantwerpen.be/en/staff/joachim-deweerdt/public-data-sets/khds/

and income.[16] We then compute rainfall deviations (in millimeters and in absolute values) from the rainfall historical mean in each cluster and in each year.

Our measure of rainfall shocks, called $Rainfall\ Shock,\ Age\ \ a_{i,g,y}$ is the absolute value of rainfall deviation from the historical mean of annual precipitations during the growing seasons experienced at age a, by individual i, while living in grid g, born in year y. For example, the variable *Rainfall Shock, Age 18* measures the difference (in absolute value) between the yearly millimeters of rainfall during the growing seasons in the grid of residence of the respondent when she/he was 18 and the historical mean of rainfall for the same grid during the growing seasons. All villages belonging to the same grid have the same historical mean and rainfall deviation. But individuals can reside in different grids during their teenage years, and this variable tracks their location at each age. By using this measure of rainfall shocks, we aim at capturing anomalously high and low rainfall realizations relative to what is typically experienced in a particular location. Similarly, we compute measures of average rainfall shocks within some age ranges: 8-18 and 15-18, 16-18, 17-18. Therefore, the variation in our measure of rainfall shocks comes from a combination of 10 grids and 27 cohorts (1965 to 1991). This combination generates, for example, 187 different shock realizations at the age of 18 across 1,246 men and women.

[Insert Figure 3]

In Figure 3, we report the yearly average level of rainfall in the growing seasons for each year across the 51 villages in our sample. The historical annual mean level of precipitation during the growing seasons is about 878 millimeters per year. As a comparison and to check the reliability of rainfall data for Kagera region, Virginia (USA), a state of a similar size as Kagera (42,774.93 kilometer squared) records an average yearly rainfall precipitation of 1100.33 millimeters (NOAA - National Centers for Environmental Information). Figure 3 shows considerable variation above and below the historical rainfall average.

[Insert Figures 4 and 5]

[16]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 is in January/February.

In Figures 4 and 5 we report the variation in our measure of rainfall shocks average between respondents aged 17-18 years old within each grid and across year of birth (Figure 4) and within year of birth and across grids (Figure 5). We show that individuals living in the same grid when they were 17 or 18, are exposed to different shocks if born in different years and that individuals born in the same year but residing in different grids when they were 17-18 were exposed to different shocks. The mean and the standard deviation of our measures of rainfall shocks in respondent's life cycle is reported in Table 2, Panel C.

4.3 Rainfall shocks and household consumption

[Insert Table 3]

In Table 3, 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 food household consumption (columns 1-5) and per capita total household consumption (columns 6-10) using the entire KHDS panel dataset from 1991 to 2010. We run OLS regressions with grid and year fixed effects. Food consumption per capita is the sum of household food consumption in the past 12 months, divided by the household size. Similarly, total consumption per capita includes the sum of all non-food expenditure (i.e., batteries, soap, umbrella, newspapers, haircuts, etc.) plus expenditure in health, education, funeral and utilities plus food consumption of the household in the past 12 months, divided by the household size. The average food consumption per capita is 820041.4 TZS (standard deviation 1365730) and the average total consumption per capita is 1220430 TZS (standard deviation 948556.5) corresponding to about 353,12 US$ and 525.54 US$, respectively.

Note that our measure of rainfall shocks is computed between March and May and between October and December in a given year, while household consumption is collected 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 3 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 5% level in all the specifications, suggesting that negative rainfall shocks are important determinants of a household's resources, as they are transferred into consumption change. In our preferred specifications, in columns 5 and 10 of Table 3, one standard deviation increase in our measure of rainfall shock at time $t-1$ (with mean equal to 127.42 and standard deviation equal to 99.48) decreases yearly food consumption by 4.8% (column 5) and yearly total consumption by 4.5% (column 10).

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 questions about consumption. In columns 4-5 and 9-10 of Table 3, 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 shocks at time $t-1$ and consumption measured retrospectively at time t. In the analysis of the impact of shocks on child marriage we indeed always allow for the possibility of lagged shocks to have an effect on marriage outcomes by considering multiple years of shocks[17].

5 Empirical Strategy

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

$$Y_{i,g,y} = \alpha + \sum_a \beta_a Rainfall\,Shock\,,\,Age\,a_{i,g,y} + \lambda X_{i,g,y} + \delta_v + \gamma_y + \epsilon_{i,v,y} \qquad (1)$$

where $Y_{i,g,y}$ takes value 1 if person i, in grid g, born in year y, got married in the year she turns 18 or before, and 0 otherwise. $Rainfall\,Shock, Age\,a_{i,g,y}$ is our proxy for income shocks experienced by person i at different ages a, given her grid of residence at that age. It is computed as the absolute values of the rainfall deviation from the historical mean in each village. $X_{i,g,y}$ is a

[17]Various alternative measures of weather variation were explored (i.e., standardized rainfall shocks, proportional change in rainfall from the previous year; the growing degree days (GDD) variation from its historical mean in each cluster). Although some of these measures are positively and statistically significantly correlated with household's consumption in our sample, they are less precisely estimated.

set of individual controls which include dummies for the highest level of education of respondent's mother and father; a dummy equal to one if the respondent lives in urban area and a dummy for an inadequate type of dwelling.[18] Grid fixed effects (δ_v) and year of birth fixed effects (γ_y) are included in the estimating equation, to capture time-invariant grid characteristics (e.g., richer versus poorer grid) and time-invariant cohort characteristics (e.g., marriage reforms in some particular year) that may be related to the probability of early marriages. Compared to Corno, Hildebrandt and Voena (2020), by including year of birth fixed effects, our empirical analysis allows us to control for aggregate shocks at the regional level, rather than at the country level or continent level, and hence to examine the impact of shocks holding constant the conditions in smaller geographic areas.

Our coefficients of interest are the β_as, which capture how income shocks affect the probability of marrying before or at age 18: a positive coefficient indicates that an adverse rainfall shock at age a increases the probability of child marriage. We estimate equation (1) using OLS with standard errors clustered at the grid level. Given the small number of grids, we wild bootstrapped the p-values using the Cameron, Gelbach and Miller (2008) procedure[19]. We report results for the sample of married individuals, separately for women and men.

6 Empirical Results

We now present our findings on the relationship between rainfall shocks and child marriage, exploring heterogeneity in the effect of shocks by local customs and household composition.

6.1 Child marriages and rainfall shocks

[Insert Table 4]

Table 4 reports the estimated coefficients for equation (1) for the sample of females. The results are in line with our model: girls exposed to adverse rainfall shocks in the age between 8 and 18 years old are more likely to get married before their 18^{th} birthday. In terms of magnitude, a one standard deviation increase in the variable capturing negative rainfall shocks during teenage

[18] 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.

[19] Results are quantitatively and qualitatively very similar when the clustering is at the village level.

years (8-18) (relative to the historical local mean) increases a girl's probability to be married by 18 by 10.7 percentage points. This effect corresponds to a 36% increase in child marriage probability compared to the mean and the effect is statistically significant at 5% level (column 1) computing wild bootstrapped p-values following Cameron, Gelbach, and Miller (2008). This finding is robust to the inclusion of controls for parents' education, a dummy indicating if the respondent resides in urban area and an index capturing whether the respondent lives in an inadequate house, computed using the principal components of wall, floor and roof made by mud, bamboo tree or earth (compared to those made by iron, stone or cement) (column 2). Among the controls, it is interesting to note that the coefficient on mother secondary education and above is negatively and statistically significant correlated (at 1% level) with early marriages, suggesting that mother's education is an important driver for better marriage outcomes for girls (see Appendix Table A2) .

In columns 3-8 of Table 4, we focus on marriages and shocks that happened between 15 and 18 years, given that the highest fraction of child marriages in our sample is within this age range (only about 2.7% of marriages happened before 15 years) and so our estimates are computed on a larger sample. Specifically, in column 3 we investigate the average effect of adverse rainfall shocks that happened when a girl was 15, 16 or 18 years old on the likelihood to be married between 15 and 18 years old. Girls exposed to adverse rainfall shocks between 15 to 18 years of age have a higher probability of being child brides. In column 4, we separately look at the effect of rainfall shocks at 15, 16, 17 or 18, showing that negative rainfall shocks are always positively correlated with early marriage for women and the magnitude of the coefficient monotonically increases. In columns 5-8 we look at the influence of shocks restricting the sample to marriages that occurred between 16 to 18 years (columns 5-6) and between 17 to 18 (columns 7-8). In all the specifications, rainfall shocks during adolescence generate a higher probability of early marriages for girls. In terms of magnitude, in column 7, a one standard deviation increase in the rainfall shock at ages 17-18 (a decrease or an increase in rainfall relative to the historical local mean) is associated with a 7.6 percentage points higher probability of early marriage and the effect is precisely estimated at 1% level.

The results for the sample of males are reported in Appendix Table A3. In stark contrast, adverse rainfall shocks do not appear to significantly 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, 2008). Björkman-Nyqvist (2013) also found that, in Uganda, a negative income shock has an adverse effect on the test scores of female students while boys are not affected, a finding consistent with a model where parents' values of child labor and productivity differ across genders. Young men may be able to rely on other margins of adjustment, such as labor supply or temporary migration, to cope with shocks (Morten (2019) and De Weerdt and Hirvonen (2016)), as opposed to delaying marriage.

Our main takeaway from this section is therefore that adverse rainfall shocks during adolescence lead to an increase in the probability of child marriages for girls but not for boys. The findings are in line with our theoretical framework and seem to fit well with our model: households hit by negative income shocks have a higher marginal utility of consumption and are more likely to marry off their daughters to receive the bride price transfer from her future groom. Negative shocks do not appear to significantly affect the timing of marriage of boys: they may be inclined to marry less (given that they have to pay a bride price in a time of low income) but this effect is not statistically significantly different from zero. In Section 6.4, we investigate the effect of income shocks on later years marriage's probability for boys, confirming that rainfall shocks do not influence the time of marriage of men.

6.2 Rainfall shocks and bride price amounts

[Insert Table 5]

Next, in Table 5, we investigate the correlation between rainfall shocks in the respondent's life cycle and the amount of the bride price payment in our sample. If the shocks are large enough to influence the entire 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 payments.

This does not seem to be the case in our data. As reported in Table 5, in all the specifications, the coefficients on negative rainfall shocks at different ages can be positive or negative and not statistically significant. Hence, we find no support for the hypothesis that the changes in the supply of brides caused by the shocks may be affecting the whole marriage market. One caveat is that the sample size is relatively small, and hence it is not possible to rule out an effect in either direction.

Marriage migration due to patrilocal exogamy may be a crucial reason for why we do not observe significant local price effects: rainfall shocks may be covariate with regards to the communities in which the young women reside, but they do not seem to be covariate in terms of the range of villages into which they marry. In Appendix Table A4 we provide further evidence of this phenomenon. The survey investigates the number of different locations where the respondent lived since 1994 and the main reasons for moving.[20] First, we observe that migration is a common phenomenon in Kagera: 58% of women and 41% of men in our sample migrated since 1994 (Table A4, Panel A). Second, in Panel B, Table A1, we report the main reasons for migration and show that nearly 34% of women declare that marriage is the main reason for migrating compared to only 3.5% of males. This is due to the practice of virilocality: brides, after marriage, move to live with their groom's family, suggesting that spouses generally do not come from the same village. Third, in Panel C, it is interesting to note that the fraction of women reporting marriage as the main reason for migration is higher among those who married before or in the year turning 18 compared to those who married older. Finally, using the same dataset, Hirvonen and Lilleør (2015) also documents that the end of a marriage is the main reason for return migration to a woman's village of origin.

6.3 Child marriage and rainfall shocks: heterogeneity analysis

6.3.1 Bride price received by married neighbouring women

Do bride price payments play a role in the observed positive relationship between rainfall shocks and girls' early marriages? One of the great advantages of the KHDS is that it elicits information on bride price amounts. This information allows us to investigate whether the relationship between

[20]The exact question in the KHDS is "Now I would like to ask you about the different places in which you lived since 1994. I'd like to know how many times you have moved since 1994, but excluding moves within the same village/town/city and excluding short-term stays of under six months" and "What was the main reason for moving?".

rainfall 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 to married respondents or to respondents who have been 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 grandparents; the second one investigates how much was it worth and the third one elicits the year of marriage. To partially alleviate the endogeneity problem coming from the direct estimation of bride price payment on child marriage, we construct a variable called *Village bride price during youth* capturing the average bride price amount received by the women living in the same village of the respondent and married when the respondent was between 8-18. The average bride price of the neighboring women when the respondent was 8-18 was 120,560 Tanzanian Shillings (approximately 37.42$). The idea behind this newly-constructed variable is that the bride price amount received by the women living in the same village as the respondent when she was an adolescent may provide an indication to parents on how much they can get by marrying their daughter at a certain age given the norms in the village. Different from the strategy used by Ashraf et al. (2020) and Corno, Hildebrandt and Voena (2020), we cannot exploit variation in ethnic origin to isolate the effect of bride price on outcomes given that the great majority of the respondents (64%) belong to the same ethnic group (Haya). One important caveat in this type of heterogeneity analysis is that the average level of bride price in a village may be correlated not only with bride price customs, but also with village characteristics at a given point in time, and particularly with its wealth. Wealth, however, would likely lead to an attenuation of the effect of rainfall, because wealthier villages may have access to better insurance technologies, rather than an exacerbation of the effect that we expect if the variable primarily captures village norms around the size of the bride price.

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 women living in the same village as the respondent when she aged 8-18 and married in the same age range. Note that, given the concern described above, in our regressions we include controls for household consumption per capita at the time of the survey and its interaction with rainfall shocks.

Results are reported in Appendix Table A5, columns 1-4. We show that the interactions between adverse shocks and the bride price amount of the neighboring woman are positive in all the specifications and statistically significant at 5% level when focusing on shocks that happened between 17-18 years old. This finding suggests that girls exposed to rainfall shocks while living in villages where the average bride price is higher have a higher probability of being child brides.

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

6.3.2 Household composition

We next explore what factors influence the responsiveness of child marriage to rainfall shocks. In particular, we investigate whether our main effect changes depending on respondent's household composition, i.e. mainly the number of sisters and brothers. Indeed, depending on the number of sisters and brothers in the household, a girl can be more or less "insured" against economic shocks. For example, a girl living in a household with at least one sister is, in principle, more insured against early marriage given that the sister can be married instead of her.[21] We exploit the information in the KHDS related to the relationship each respondent has with the household head (i.e., head, spouse, son/daughter, grandchild, siblings, father/mother, niece/nephew, son/daughter in law, siblings in law, tenant, other relatives). We focus on the sub-sample of daughters in each wave and compute the number of sisters and brothers during respondent's teenage years. We then test how the effect of rainfall shock on early marriage's probability varies depending on the number of sisters (and brothers) each daughter has.

Appendix Table A5 columns 5-8 reports the estimated coefficients for equation (1) for women, augmented with the interaction between rainfall shocks at different ages and the number of sisters and brothers for the individual i during youth, controlling for the size of the household. We show that the coefficient on the interaction term between our measure of rainfall shocks and the number of sisters the respondent has during youth is negatively correlated with the respondent's probability of marriage by 18, suggesting that individuals with sisters are more insured against income shocks

[21] It would be extremely interesting also to test whether the number of younger versus older sisters/brothers would have a differential effect on a respondent's probability of child marriage. Unfortunately, given the small sample size, we cannot exploit this additional heterogeneity.

and less likely to be married earlier: in case of rainfall shocks, there is a higher number of potential brides to count on.

6.4 Robustness Checks

In this section, we conduct a series of robustness checks to validate our main results reported in Table 4 - the effect of rainfall shocks on early marriage for women - and in Appendix Table A3 - the effect of rainfall shocks on early marriage for men.

First, in Appendix Table A6, we study the persistence of the effect of income shocks on marriage probability. In particular, we look at the probability of marriage by 19-20, 21-22, 23-24 years, separately for women and men. In columns 1-6 we show that the effect of adverse rainfall shocks in a women's life cycle does not persist at later marriages (marriages that happen after 18). Furthermore, in principle, the fact that we do not find any impact on the effect of rainfall shock during youth on child marriage for boys, as reported in Table A3, might be possible due to the fact that fewer boys marry by the age of 18. However, even when expanding the age range for boys (columns 7-12) we still don't find any association between rainfall shocks and marriage probability. One possibility is that men may rely on other margins of adjustment, such as labor supply or temporary migration, to cope with shocks (see for example studies by Morten (2019) and De Weerdt and Hirvonen (2016)), as opposed to delaying marriage.

Second, as a further robustness test, in Appendix Table A7, we check whether our measure of negative rainfall shocks is correlated with the probability of being married between 13-14 (columns 1-3) and between 14-15 (columns 4-7), hence *before* the shock occurs. Negative shocks that hit individuals at certain ages should not influence their prior marriage probability. For both girls (columns 1-5) and boys (columns 6-7), negative rainfall shocks at 15 to 18 do not influence the probability of marriage at 13-14 and shocks at 16 to 18 do not affect the likelihood of marriage at 14-15. Given the small number of marriages at 13-14 for boys, we cannot estimate the coefficients reported in columns 1-2 for the sample of males.

7 Structural estimation and policy counterfactual

In this section, we estimate the parameters of the model described in section 3, exploiting the reduced-form evidence that we have presented above to inform the estimation. We will then use the structural estimates to perform policy simulations that allow us to assess the role of child marriage and of bride price in smoothing households' consumption in response to adverse economic shocks.

We begin by discussing the parametrization of preferences and income, then discuss the estimation of all the structural parameters of the model by indirect inference, and finally perform two sets of policy simulations: we assess the effects of child marriage bans and cash transfer programs.

7.1 Parametrization

Preferences We set the utility function for all the households to be have constant relative risk aversion (CRRA), with coefficient of relative risk aversion denoted as b:

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

We set the utility benefit associated with marriage at age a, denoted as ξ_a, as sixth-degree polynomial in years since age 14 ($\alpha = a - 13$):

$$\xi_a = \sum_{i=0}^{6} k_{i+1}\alpha^i.$$

This specification allows it to flexibly account for parental preferences over their daughter's age of marriage, which may be non-monotonic: parents may dislike early marriage, but may also dislike the prospect a delaying their daughter's marriage too much.

Budget constraint Income y_a is distributed as log-normal distribution with mean μ and variance σ^2, drawn independently every year. Consistently with what we observe in the KHDS data, where average income does not vary with the household head's age, μ is fixed and does not vary with age.

Another monetary component of the model is the bride price, which depends on a woman's age. We compute the bride price amount $BP(a)$ from the data as a fourth-degree polynomial.[22]

Timing Consistent with the distribution of ages at marriage, we restrict marriage to occur between age 14 and age 34, since few marriages occur outside of this interval.

7.2 Structural estimation by indirect inference

We estimate the vector $\boldsymbol{\theta}$ of parameters of the model, which include the coefficient of relative aversion b, the discount factor δ, the mean and variance of income μ, σ^2 and the parameters governing parental preferences of age of marriage $\{k_1, ..., k_7\}$. We estimate the model by indirect inference (Gourieroux, Monfort and Renault, 1993). This method is based on finding the set of structural parameters that minimize the distance between the parameters of an auxiliary model estimated on the actual data (denoted as $\hat{\boldsymbol{\phi}}^{data}$) and those estimated on simulated data ($\boldsymbol{\phi}$). Therefore, the estimated parameters are found by solving the following problem

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

where G is the optimal weighting matrix.

Auxiliary model As auxiliary model, we use summary statistics from our data and the reduced-form model presented above.

In particular, the vector of estimated parameters of the auxiliary model comprises of three components. First, it includes the vector of the probability of marriage for women by each age

[22]The function BP_a is estimated directly in the data (Appendix Figure A2). We estimate the profile of bride price payments over a women's age of marriage in the KHDS data. 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 - dummies for primary, secondary and tertiary education - (specification #1); adding controls for parental assets at the time of marriage - livestock - (specification #2); adding wedding year dummies (specification #3) and parental education - primary and secondary or above - (specification #4). The estimates are relatively stable across specifications, and we use the most demanding one in the estimation.

between 14 and 34: $\boldsymbol{\phi_1} = \{P(M_a = 1)\}_{a=14}^{34}$. In our model, each of these probabilities is equal to:

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

Second, we set three parameters of the auxiliary model as the elasticity of female teenage marriage to consumption shocks at ages 16, 17 and 18 (Table 5 column 4). We focus on these three effects because they are the relatively more precisely estimated ones , and hence will have have greater role in the estimation since the optimal weighting matrix weighs precisely-estimated auxiliary parameters relatively more than other auxiliary parameters. Moreover, by measuring the effects at each age separately, we expect that the model will match the fact that these responses increase with a woman's age. Therefore, following the approach we have taken in the empirical analysis, we estimate the following linear probability model on the simulated data and on the KHDS data:

$$
P(m_{16,17,18} = 1)_i = \delta_1 + \psi_1 \cdot ln(C_{i,16}) + \psi_2 \cdot ln(C_{i,17}) + \psi_3 \cdot ln(C_{i,18}),
$$

where $m_{16,17,18}$ takes value one if the woman marries between ages 16 and 18, $C_{i,a}$ is aggregate consumption of household i with a daughter of age a, hence $C_{i,a} = y_{i,a} + BP_a m_{i,a} = c_{i,a}$.

Then, we set $\boldsymbol{\phi_2} = \{\psi_1, \psi_2, \psi_3\}$.

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:

$$
\begin{aligned}
&P(m_{16,17,18})_i = \delta_1 + \beta_1 \cdot Shock\,at\,16_i + \beta_2 \cdot Shock\,at\,17_i + \beta_3 \cdot Shock\,at\,18_i + \boldsymbol{\lambda_1}'\mathbf{X}_i \\
&ln(C_{i,t-1}) = \alpha + \eta \cdot Shock_{i,t-1} + \boldsymbol{\gamma}'\mathbf{X}_i + \epsilon_{it}
\end{aligned}
$$

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. The first equation corresponds to the one estimated in Table 4 (column 6) and the second equation to the one estimated in Table 3 (column 7). We set ${\boldsymbol{\phi_2}}^{data} = \left\{ \frac{\beta_1}{\eta}, \frac{\beta_2}{\eta}, \frac{\beta_3}{\eta} \right\}$.

Third, since we also intend to estimate the mean and variance of the income process, we include the mean and variance of the logarithm of household consumption in the auxiliary model. These are two additional auxiliary parameters, denoted as $\boldsymbol{\phi_3} = \{E[ln(C)], Var[ln(C)]\}$, where:

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

Using consumption variability to estimate the variability in income has the advantage of allowing us to identify a process for y which is net of other income and consumption smoothing strategies that households have access to and which are outside of our model.

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 $\hat{G} = Var[\boldsymbol{\phi}^{data}]^{-1}$.

[Insert Figure 6]

Estimation To examine how the model fits the auxiliary parameters that are explicitly targeted in the estimation, Figure 6 reports the estimated parameters of the auxiliary model in the KHDS data (with the 90% confidence interval) 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 25 and 26, or $\boldsymbol{\phi_3}$). The model also accounts for a large fraction of the response of the probability of marriage with respect to rainfall shocks at ages 16, 17 and 18 (parameters 22, 23, and 24 or $\boldsymbol{\phi_2}$), but not for the whole response. This is also due to the fact that these moments, even though they are relatively more precisely estimated than other marriage age elasticities, are still more noisy than other moments based on sample means, as can be seen from the wide confidence intervals, and hence receive relatively lower weight by the optimal weighting matrix.

[Insert Table 6]

Table 6 reports the estimates for vector $\boldsymbol{\theta}$ and their standard errors. We estimate the coefficient of relative risk aversion to be equal to 0.39 and the discount factor equal to 0.36. Given the estimates for $\mathbf{k}$, the resulting values of ξ_a between ages 14 and 34 are positive but small early on, peak at age 21 and then drop after that to then increase again in later ages.Daughters contribute to about 5% of household per capita consumption. Estimated average log-income μ is 14.883 , which generates a simulated average log-consumption of 14.884 . The estimated variance of log-income σ^2 is 0.209 , which generates a simulated variance of log-consumption of 0.202 .

These estimates indicate that liquidity considerations play a significant role in explaining the prevalence of child marriage: parents prefer to avoid child marriage, and daughters are productive. Therefore, when income is low and hence marginal utility of consumption high, the bride price plays a larger role in causing early marriage, which would happen later if households did not face liquidity constraints.

7.3 Policy simulations

In this section, we study two types of policy simulations that examine the effect of policies meant to discourage child marriage: age bans, under which marriage below a certain age is prohibited, and cash transfer programs, in which households with young daughters receive payments that are unconditional or conditional on the daughter remaining unmarried.[23]

7.3.1 Child marriage bans

[Insert Figure 7]

Laws that impose a minimal age of marriage are widespread around the world. For example, in 1971, Tanzania's Marriage Act set the minimum marriage age for girls at 15 with parental consent, and 18 for boys. It permitted 14-year-old children to marry when a court is satisfied that special, although unspecified, circumstances exist. Exceptions, customary marriages and the lack of birth records that certify a child's age are often a way by which such bans are evaded

[23]Other policies, such as investments in girls' schooling, may be very effective, in the medium term, at reducing child marriage.

throughout Sub-Saharan Africa (Jensen and Thornton, 2003; Walker, 2012; Arthur et al., 2018; Wilson, forthcoming).[24] Indeed, in 2016 and again in 2019, Tanzanian high courts ruled such exceptions as unconstitutional, and directed the government to raise the legal age of marriage to 18 years, in spite of government's appeals.[25]

While a full evaluation of such these policies would entail analyzing these important implementation issues, we limit our analysis to understanding the implications of a child marriage ban on the distribution of ages at marriage if it were fully enforced. To do so, we simulate two counterfactual exercises:

a) a child marriage ban that prohibits marriage below the age of 16;

b) a child marriage ban that prohibits marriage below the age of 18.

An interesting implication of banning child marriage is well captured by Figure 7, which shows the cumulative probability of marriage at each age without marriage bans and under the two different bans we simulate. After a ban is no longer binding, marriage rates do not increase immediately to the levels they would have achieved without the ban, but slowly adjust, leading to a persistent shift in the average age of marriage, which shifts from 20.7 years old at baseline to 21.1 years old with an age 16 ban and 21.9 with an age 18 ban. This pattern is due to the fact that the ban on child marriage prevented marriages that would only have occurred to smooth income shocks, and these households may not choose to have their daughter marry as soon as she reaches the legal age of marriage. Hence, a ban on marriage before age 16 actually reduces overall marriage before age 18 by 14.6% (or 4.2 percentage points) and a ban on marriage before age 18 has a persistent effect up to a woman's mid-twenties.

Because child marriage is used by households as a consumption-smoothing mechanism, banning it does limit the ability of households to smoothen their consumption. This could make an age ban costly for households, limiting the popularity and the sustainability of such a policy. To examine the implications of a marriage age ban on parental utility, we compute the consumption equivalent (equivalent variation) of the marriage age ban with the formula:

[24] See, for example, https://www.girlsnotbrides.org/articles/how-important-is-minimum-age-of-marriage-legislation-to-end-child-marriage-in-africa/. Last accessed February 7 2022.

[25] See `https://www.cnn.com/2019/10/23/africa/tanzania-court-child-marriage-ban-intl/index.html`, last accessed April 8 2022.

$$\sum_{k=1}^{K}\sum_{t=14}^{T}\delta^{t-1}\left[\frac{((1+\pi)c_{B,t})^{1-b}}{1-b}+m_{B,t}\cdot\xi_t\right]=\sum_{k=1}^{K}\sum_{t=14}^{T}\delta^{t-1}\left[\frac{(c_{CF,t})^{1-b}}{1-b}+m_{CF,t}\cdot\xi_t\right] \quad (3)$$

The consumption equivalent captures the change in lifetime per-capita consumption, over the 28 years of life of the household from age 14 of the daughter onward, that equates the utility of the household at baseline to the utility of the household under the policy.

We find that age bans have relatively small utility costs to the parents, equivalent to -0.14% of the lifetime per-capita household consumption for an age 16 ban and -0.18% of lifetime per-capita household consumption for an age 18 ban (Table 7 panel A). These small costs do not account for any potentially positive impact of the bans on daughters, to the extent that the daughter's utility is not fully incorporated in the parents' preferences. They therefore do not represent the entire welfare effect of the age ban. They do, however, indicate that the cost of parents may be relatively small.In addition, over time child marriage bans may influence attitudes over early marriage and lead to a change in parental preferences. Such a shift, which is not taken into account by our simulations, could further reduce the utility cost faced by parents and eventually make the ban non binding.

We consider an alternative scenario, in which the consumption-smoothing effect of child marriage is mitigated by the presence of perfect credit markets, by allowing households to borrow and save, modifying the budget constraint in the following way:[26]

$$c_a(s^a)\cdot(1+e\cdot(1-M_a(s^a)))+A_{a+1}(s^a)\leq y_a(s_a)+BP_a\cdot m_a(s^a)+(1+r)A_a(s^{a-1})$$
$$A_1(s^1)=A_{T+1}(s^T)=0.$$

Allowing for credit markets eliminates the use of the timing of marriage as a consumption smoothing device, shifting the distribution of ages of marriage. This reduces the utility costs of marriage bans, making the utility cost of an age-16 ban 4.8 times smaller (0.029%) than in the absence of a credit market, and the utility cost of an age-18 ban 4.3 times smaller (0.041%), as

[26] We calibrate the interest rate r to be equal to 12% (Bank of Tanzania, 2010).

reported in panel B of Table 7. This policy exercise indicates that accompanying policies that discourage child marriage with complementary policies that improve households' ability to insure their consumption may further reduce any backlash from the policy and help policymakers to balance the potential social benefits of the policy with the costs that the household faces.

7.4 Conditional and unconditional cash transfers

An alternative, incentive-based policy tool that has been studied to combat child marriage is cash transfers. Baird, McIntosh and Özler (2011) show that an unconditional cash transfers program targeted to the households of young teenage girls reduces teenage pregnancy and marriage in Malawi. Transfers conditional on remaining unmarried are being studied in India (Sinha and Yoong, 2009) and Bangladesh (Buchmann et al., 2021). We use our model to quantify the effect of reducing child marriage through these different policy levers, and to assess the utility benefit to households. Note that these are partial equilibrium analyses that cannot account for the effect of the subsidies on prices, and hence should be interpreted in the context of small-scale interventions.

We consider three policies:

1. a conditional program (CCT) that makes a cash transfer to households with a daughter up to age 18 as long as the daughter is unmarried;

2. an unconditional program (UCT) that makes a cash transfer to all households with a daughter up to age 18, irrespective of their marital status

3. an unconditional program (UCT25) that makes a cash transfer to households whose income is below the 25th percentile if the income distribution and with a daughter up to age 18, irrespective of her marital status.

We iterate on the size of the program transfer to compute how large each type of transfer ought to be to reduce child marriage by 20%, 50% and by 100%, thereby eliminating the child marriage entirely. Table 8 reports the outcomes.

The simulations lead to a few interesting findings. In line with the results in Baird, McIntosh and Özler (2011), we observe that unconditional cash transfers can reduce child marriage. Not surprisingly, transfers that are conditional on remaining unmarried are significantly less costly, at least from a direct cost perspective.[27] Our simulations suggest that unconditional cash transfers would require about twenty times larger direct costs to achieve the same reduction in child marriage. Nevertheless, the same reduction in child marriage can also be achieved with unconditional cash transfers that target only the poorest households, as a form of social insurance. Targeting the poorest quartile of household with unconditional cash transfers, in addition to its other demonstrated benefits (Haushofer and Shapiro, 2016), can reduce child marriage at the same rate as conditional cash transfers at about six times the direct cost.

Further field-oriented research should explore how to best design such programs to maximize their effectiveness.

8 Conclusions

Despite widespread condemnation, the practice of child marriages persists around the world. Its consequences, especially among women and their children, are devastating, yet its reasons are poorly understood. In this paper, we examine the responsiveness of child marriage to income fluctuations among rural households in Tanzania, where bride price is customary, and attempt to understand effective policies potentially able to reduce the phenomena.

We develop a dynamic discrete-choice model to show that parents who are exposed to adverse income shocks have a higher probability of marrying their daughters earlier, as we confirm 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. Moreover, the relationship between rainfall shocks and child marriages is stronger in villages where the average 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 policy simulations. We find that parents prefer to delay marriage and that daughters are productive, hence the bride price plays a crucial role in determining the age of marriage. Child marriage bans, if enforceable, are effective, as they raise the age of marriage even after they are no longer binding. They are costly to

[27] Comprehensive cost-effectiveness comparisons of these different programs would require an estimate of the costs of administering each program, which are outside the scope of our model.

households, because they prevent relying on bride price payments in times of economic hardship, but the costs are not large. Conditional and even unconditional cash transfers are effective at reducing child marriage, especially when they target low-income households.

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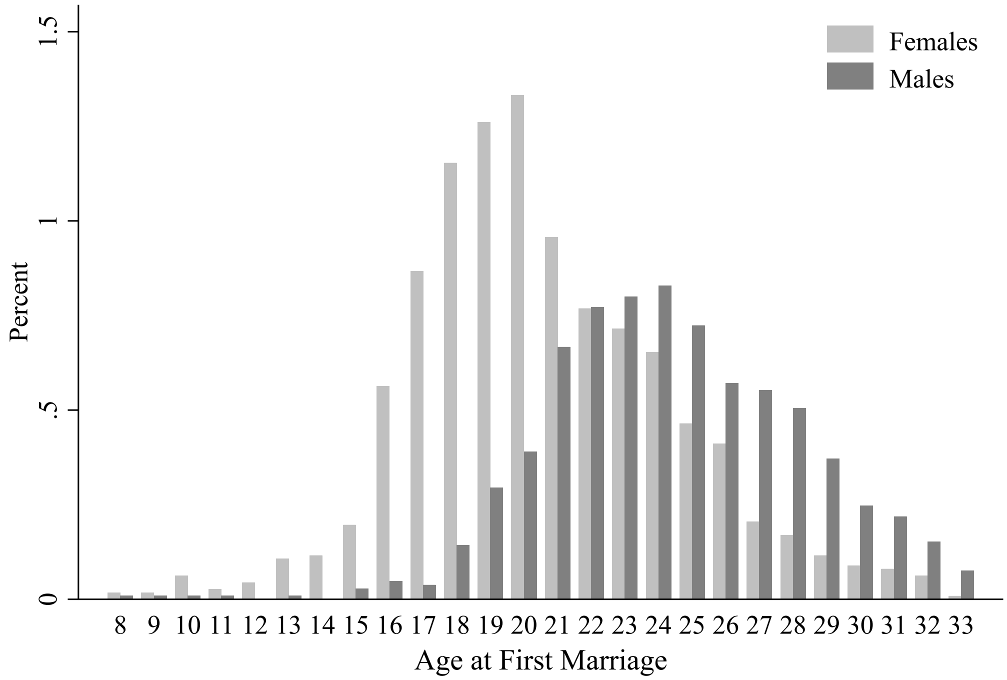
Figures

Figure 1: Distribution of age at first marriage, by gender



Notes: Sample of respondents with non-missing information on the age of marriage. Source: Kagera Health Development Survey (KHDS) 2004-2010.

Figure 2: Location of Kagera and villages across grids in our sample

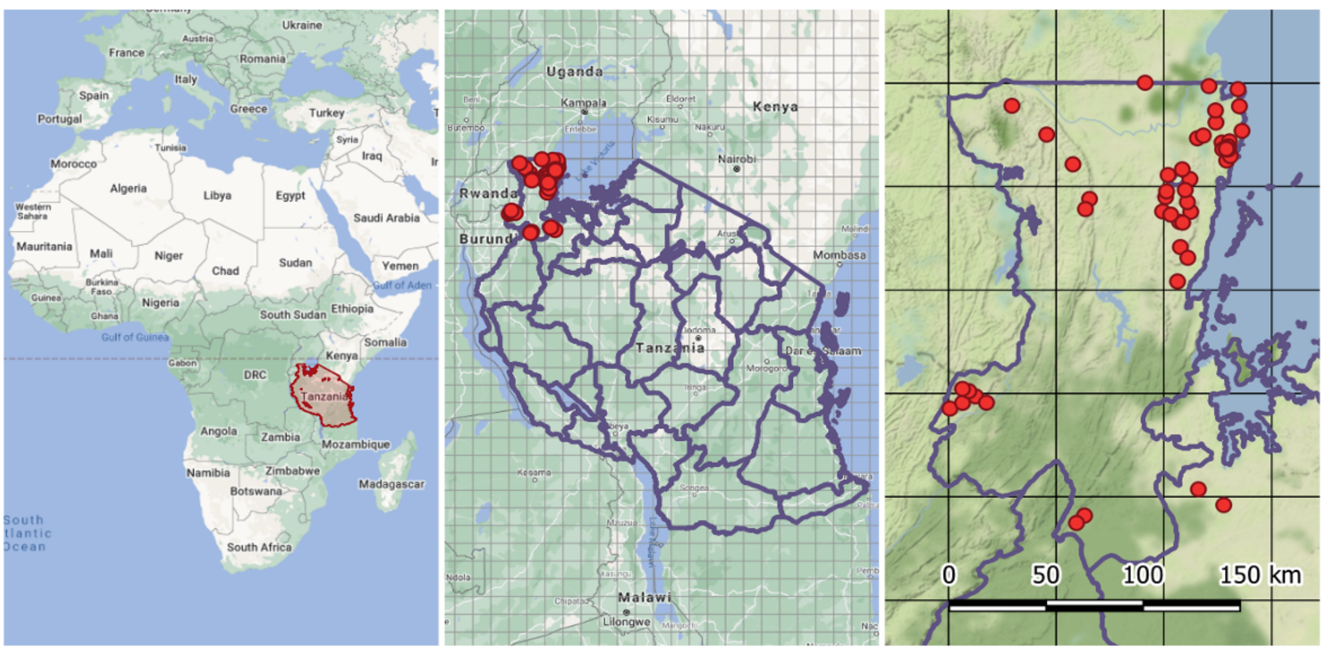
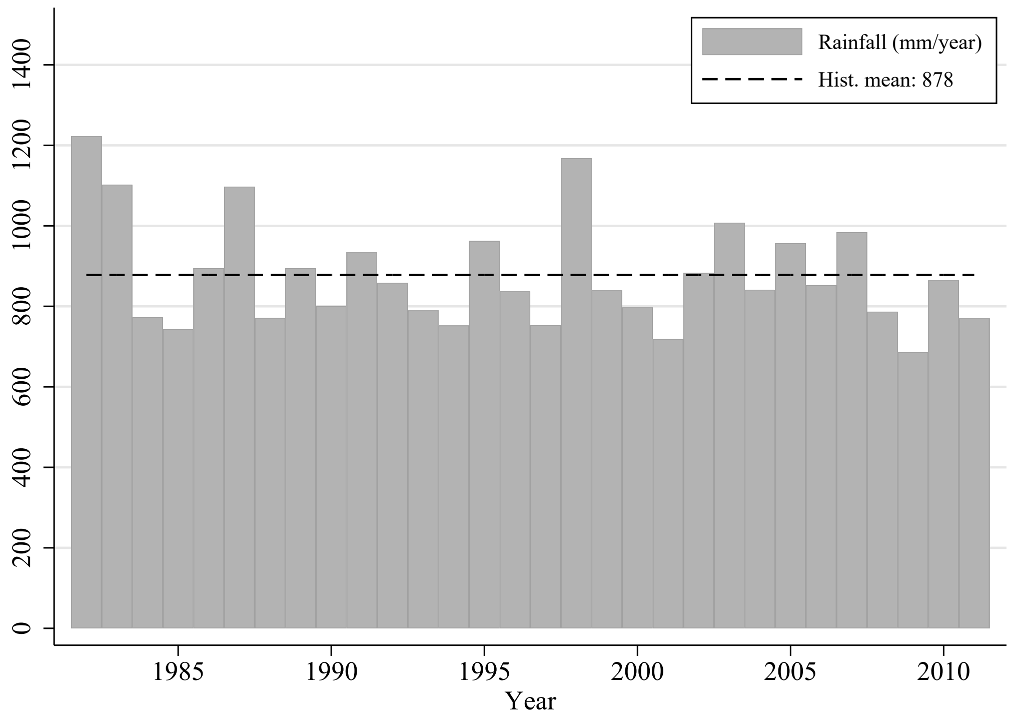
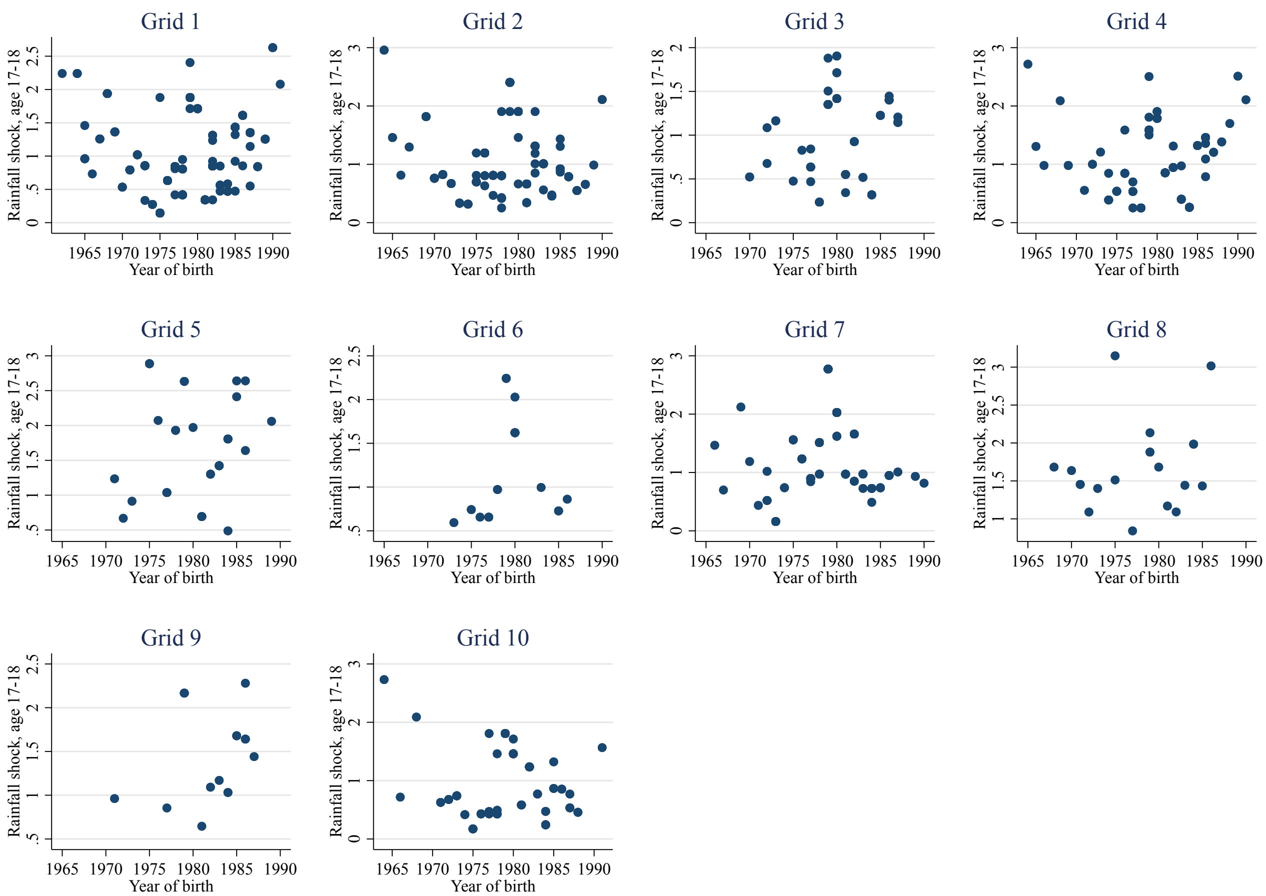


Figure 3: Yearly deviation from the historical rainfall mean



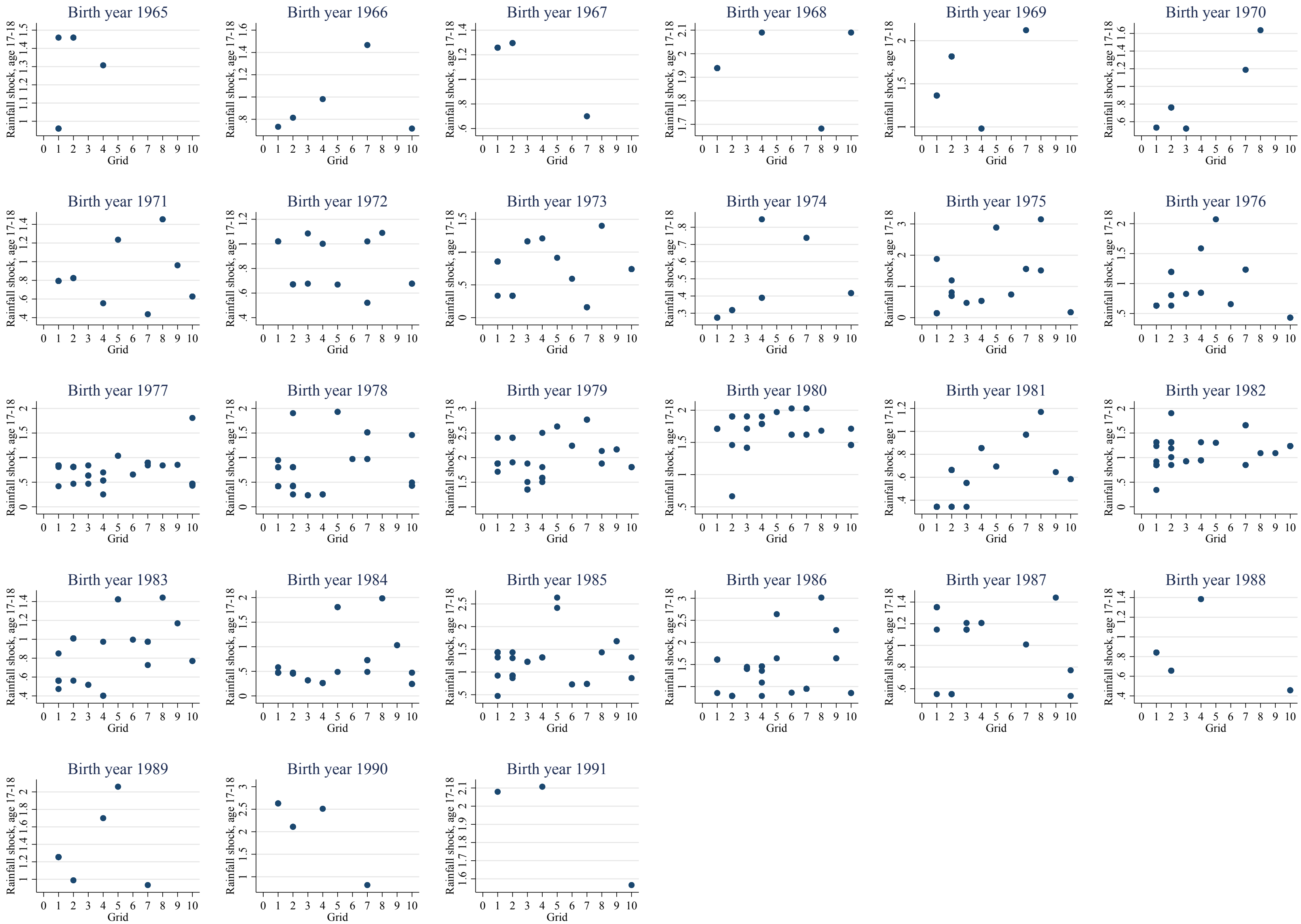
Notes: Source: NASA Langley Research Center for rainfall measures.

Figure 4: Rainfall shocks at age 17 or 18, by grid



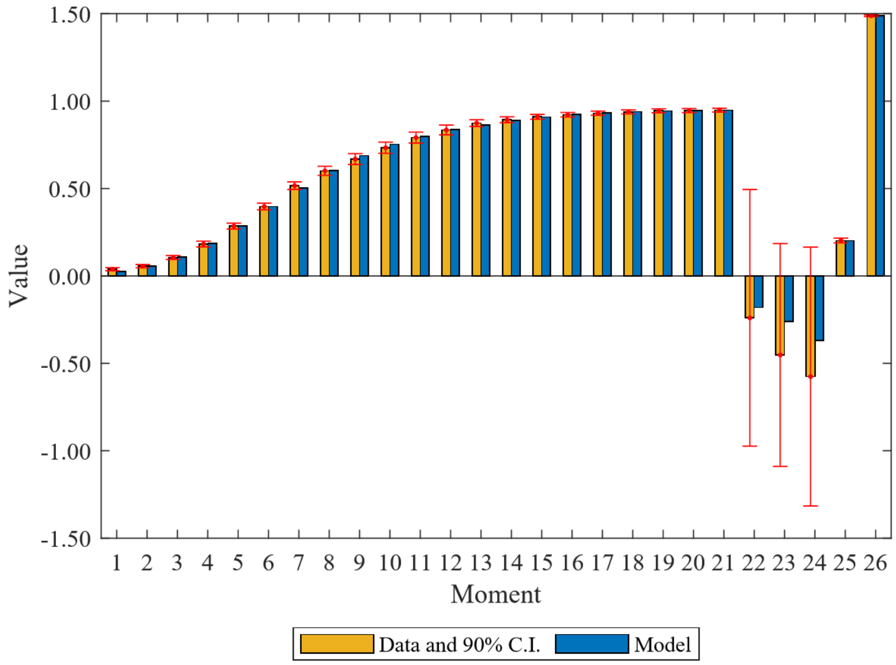
Notes: Sample of respondents with non-missing information for the age of marriage and rainfall shocks at the ages 17-18. Source: Kagera Health Development Survey, 2004-2010.

Figure 5: Rainfall shocks at age 17 or 18, by birth year



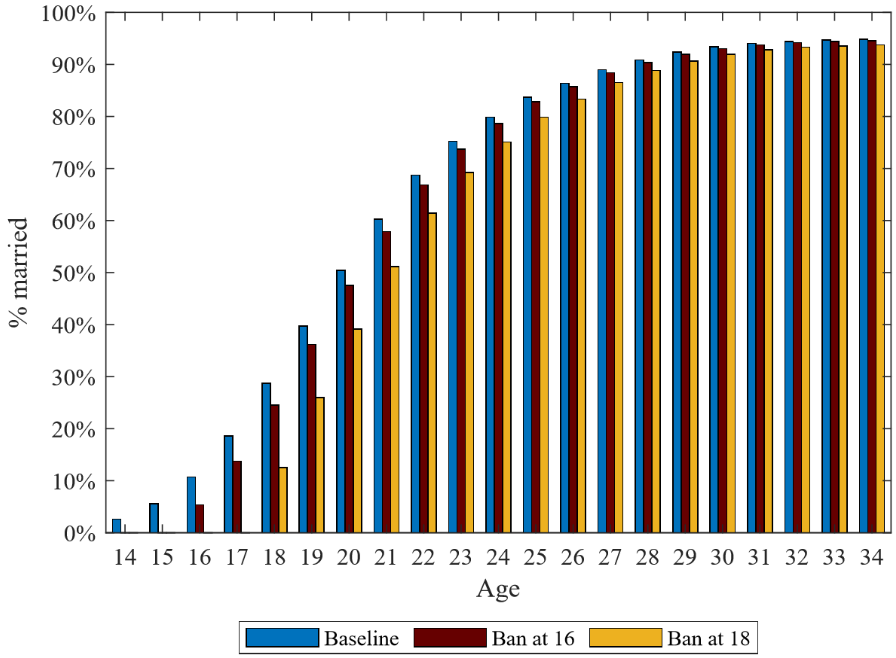
Notes: Sample of respondents with non-missing information for the age of marriage and rainfall shocks at ages 17-18. Source: Kagera Health Development Survey, 2004-2010.

Figure 6: Matching of the moments of the auxiliary model



Notes: Moments of the auxiliary model in the data and their 90% confidence intervals, and moments in the estimated model. Moments 1-21 are probabilities of marriage between ages 14 and 34. Moments 22, 23 and 24 are the elasticity of child marriage with respect to resource shocks. Moment 25 is the variance of the natural logarithm of household consumption. Moment 26 is the mean of the natural logarithm of household consumption, divided by 10 for scaling purposes.

Figure 7: Counterfactual experiment - enforcement of minimal marriage age



Notes: Probability of being married by age, under different counterfactual regimes. The baseline case is the estimated model on the KHDS data. 'Ban at 16' represents a counterfactual in which women are barred from marrying before age 16. 'Ban at 18' represents a counterfactual in which women are barred from marrying before age 18.

Tables

Table 1: Characteristics of the bride price payment

	Full sample (1)	Marriage ≤ 18 (2)	Marriage > 18 (3)
Panel A: Bride price prevalence and amount			
Bride price[a)]	0.81	0.79	0.82
	[0.39]	[0.40]	[0.38]
Bride price amount (in TZS)[b)]	115683.46	98146.69	120055.58
	[139190.84]	[105845.89]	[146059.88]
	($49.82)	($42.27)	($51.70)
Panel B: Bride price, by Type			
Paid in cash	0.62	0.57	0.64
	[0.30]	[0.30]	[0.30]
Paid in-kind (cloths, blankets, banana beer, raw meat, other foods, handtools, kerosene, others)	0.27	0.30	0.26
	[0.26]	[0.27]	[0.26]
Paid in livestock	0.08	0.07	0.08
	[0.17]	[0.17]	[0.18]
Panel C: Bride price, by Recipient			
Paid to bride's parents	0.57	0.56	0.57
	[0.43]	[0.43]	[0.42]
Paid to bride's family (aunts, uncles, grandparents, brothers)	0.38	0.41	0.37
	[0.42]	[0.44]	[0.42]
Paid to others (not parents, aunts/uncles, grandparents, brothers)	0.05	0.03	0.06
	[0.17]	[0.06]	[0.18]

Notes: Sample of respondents with non-missing information for the age of marriage and rainfall shocks at ages 17-18. Standard deviation in square brackets. All values expressed in % besides bride price amount. a) Bride price is defined as any payment made by the groom or by the groom's family to parents, aunts, uncles, grandparents, brothers and other family members of the bride for formal marriages and as any fine paid by the groom or by the groom's household for informal marriages. b) Exchange rate: 1US$= 2.322,00 TZS at April 11th, 2022. The values reported in the last three rows of the table are defined for formal marriages only. Source: Kagera Health Development Survey, 2004-2010.

Table 2: Summary statistics by gender

	Female			Male		
	Mean	*Std. Dev*	*Obs*	*Mean*	*Std. Dev*	*Obs*
Panel A: Marriage's characteristics	(1)	(2)	(3)	(4)	(5)	(6)
Age at marriage	20.37	3.71	735	24.25	3.76	511
Marriages by 15	0.06	0.24	735	0.01	0.09	511
Marriages by 18	0.30	0.46	735	0.04	0.19	511
Married between 15 and 18 years old	0.27	0.44	735	0.03	0.18	511
Married between 16 and 18 years old	0.24	0.43	735	0.03	0.17	511
Married between 17 and 18 years old	0.18	0.39	735	0.03	0.16	511
Married between 19 and 20 years old	0.25	0.43	735	0.09	0.29	511
Married between 21 and 22 years old	0.19	0.40	735	0.21	0.41	511
Married between 23 and 24 years old	0.14	0.34	735	0.23	0.42	511
Panel B: Demographic characteristics						
Urban	0.24	0.43	735	0.24	0.43	511
Bad house (PCA)	0.40	1.28	735	0.39	1.23	511
Mother no education	0.04	0.13	735	0.03	0.09	511
Mother primary (some or completed)	0.91	0.18	735	0.92	0.13	511
Mother secondary or higher (some or completed)	0.05	0.13	735	0.05	0.10	511
Father no education	0.03	0.11	735	0.02	0.10	511
Father primary (some or completed)	0.87	0.21	735	0.87	0.20	511
Father secondary or higher (some or completed)	0.10	0.19	735	0.10	0.18	511
Panel C: Rainfall Shocks						
Rainfall shock by 18	96.28	22.85	674	95.74	23.90	395
Rainfall shock, age 15-18	102.20	39.87	725	97.62	40.82	493
Rainfall shock, age 16-18	105.05	45.11	730	100.45	46.05	501
Rainfall shock, age 17-18	106.63	58.15	735	106.01	62.22	511
Rainfall shock, age 15	94.64	91.31	728	92.55	85.97	493
Rainfall shock, age 16	102.22	93.72	730	93.25	82.15	501
Rainfall shock, age 17	102.54	89.94	735	109.61	94.62	511
Rainfall shock, age 18	110.73	93.74	735	102.40	99.35	511

Notes: Sample of respondents with non-missing values for the age at marriage and rainfall shocks at the age of 17-18. Rainfall shocks are computed as 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) at each age of the respondents. The type of dwelling is described by the construction material of the floor, the roof and outside walls of respondent's household. Bad house (PCA) is the principal components of wall, floor and roof made by mud, bamboo tree or earth (compared to those made by iron, stone or cement). Source: Kagera Health Development Survey 2004-2010 for demographic characteristics and NASA Langley Research Center for rainfall measures.

Table 3: Rainfall shocks and households' consumption

Dependent variable:	*Food consumption p/c (log) (in TZS)*					*Total Consumption p/c (log) (in TZS)*				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Rainfall shock, t	0.015			0.022	0.023	0.019			0.025	0.026
	(0.026)			(0.024)	(0.025)	(0.024)			(0.023)	(0.023)
	[0.584]			[0.449]	[0.486]	[0.441]			[0.299]	[0.307]
Rainfall shock, t-1		-0.055**		-0.057**	-0.049***		-0.047**		-0.049**	-0.046***
		(0.012)		(0.012)	(0.011)		(0.014)		(0.014)	(0.012)
		[0.031]		[0.020]	[0.010]		[0.037]		[0.018]	[0.010]
Rainfall shock, t+1			-0.046		-0.022			-0.029		-0.007
			(0.025)		(0.021)			(0.024)		(0.020)
			[0.176]		[0.285]			[0.283]		[0.832]
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Grid Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mean of the Rainfall Shock	1.000	1.310	0.990			1.000	1.310	0.990		
Mean Dependent Variable	13.170	13.170	13.170	13.170	13.170	13.600	13.600	13.600	13.600	13.600
R^2	0.635	0.636	0.635	0.636	0.636	0.665	0.666	0.665	0.666	0.666
Observations	8293	8293	8293	8293	8293	8289	8289	8289	8289	8289

Notes: OLS regression on KHDS 1991-2010 panel data. Robust standard errors in parentheses, clustered at the grid level. Wild bootstrap (5000 repetitions) p-values in square brackets with corresponding *** 1% , ** 5% , * 10% significance. Constant not displayed "Food consumption p/c (log)" is the logarithm of the sum of household food consumption in the past 12 months, divided by the household size. "Total consumption p/c (log)" include the logarithm of the sum of all non-food expenditure (i.e. batteries, soap, umbrella, newspapers, haircuts, etc.) plus expenditure in health, education, funeral and utilities plus food consumption of the household in the past 12 months, divided by the household size. Rainfall shock is defined as 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 2, include dummies for mother and father highest level of education (primary education and secondary/tertiary education, with no education as omitted category), the principal component analysis for inadequate house and a dummy indicating urban areas. Source: Kagera Health Development Survey 1991-2010.

Table 4: Child marriage and rainfall shocks

Dependent variable: *If married:*	By 18		between 15-18		between 16-18		between 17-18	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Rainfall shocks by 18	0.470**	0.467*						
	(0.142)	(0.155)						
	[0.041]	[0.057]						
Rainfall shock, age 15-18			0.226**					
			(0.061)					
			[0.018]					
Rainfall shock, age 16-18					0.131			
					(0.059)			
					[0.127]			
Rainfall shock, age 17-18							0.132***	
							(0.046)	
							[0.002]	
Rainfall shock, age 15				0.025				
				(0.018)				
				[0.189]				
Rainfall shock, age 16				0.037		0.018		
				(0.044)		(0.043)		
				[0.457]		[0.770]		
Rainfall shock, age 17				0.072*		0.056		0.072**
				(0.033)		(0.031)		(0.026)
				[0.090]		[0.170]		[0.012]
Rainfall shock, age 18				0.083*		0.060		0.061*
				(0.041)		(0.038)		(0.029)
				[0.084]		[0.123]		[0.059]
Grid Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year of Birth Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mean Dependent Variable	0.300	0.300	0.260	0.260	0.240	0.240	0.180	0.180
R^2	0.055	0.083	0.093	0.095	0.087	0.088	0.089	0.089
Observations	674	674	725	725	730	730	735	735

Notes: OLS regressions. Sample of women with non-missing information on the age of marriage and rainfall shocks at ages 17-18. Robust standard errors in parentheses, clustered at the grid level. Wild bootstrap (5000 repetitions) p-values in square brackets with corresponding *** 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 2, include dummies for mother and father highest level of education (primary education and secondary/tertiary education, with no education as omitted category), the principal component analysis for inadequate house and a dummy indicating urban areas. Source: Kagera Health Development Survey 2004-2010.

Table 5: Rainfall shocks and bride price amount

Dependent variable:	*Bride price amount (log)*					
	(1)	(2)	(3)	(4)	(5)	(6)
Rainfall shock, age 15-18	0.068					
	(0.143)					
	[0.600]					
Rainfall shock, age 16-18			0.028			
			(0.111)			
			[0.801]			
Rainfall shock, age 17-18					0.044	
					(0.131)	
					[0.762]	
Rainfall shock, age 15		0.058				
		(0.040)				
		[0.246]				
Rainfall shock, age 16		0.012		-0.002		
		(0.073)		(0.065)		
		[0.777]		[0.973]		
Rainfall shock, age 17		0.089		0.076		0.076
		(0.082)		(0.078)		(0.088)
		[0.410]		[0.428]		[0.443]
Rainfall shock, age 18		-0.032		-0.020		-0.022
		(0.038)		(0.041)		(0.045)
		[0.594]		[0.732]		[0.871]
Age	-0.004	-0.006	0.003	0.004	0.003	0.003
	(0.025)	(0.021)	(0.022)	(0.019)	(0.022)	(0.020)
	[0.877]	[0.844]	[0.891]	[0.822]	[0.922]	[0.904]
At least primary edu	0.398	0.409	0.388	0.395	0.398	0.403
	(0.131)	(0.129)	(0.121)	(0.124)	(0.127)	(0.127)
	[0.131]	[0.123]	[0.141]	[0.139]	[0.143]	[0.139]
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Grid Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Age of Marriage Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Wedding Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Mean Dependent Variable	11.160	11.160	11.160	11.160	11.150	11.150
R^2	0.348	0.354	0.346	0.351	0.347	0.351
Observations	516	516	520	520	521	521

Notes: OLS regressions. Sample of women with non-missing information on the age of marriage and rainfall shocks at ages 17-18. Robust standard errors in parentheses, clustered at the grid level. Wild bootstrap (5000 repetitions) p-values in square brackets with corresponding *** 1% , ** 5% , * 10% significance stars. 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). "At least primary edu" is a dummy taking value 1 whenever the individual has completed primary education. All the coefficients (standard errors) are multiplied by 100. Controls, as described in table 2, include dummies for mother and father highest level of education (primary education and secondary/tertiary education, with no education as omitted category), the principal component analysis for inadequate house and a dummy indicating urban areas. Source: Kagera Health Development Survey 2004-2010.

Table 6: Parameter estimates

Parameter	Estimate	Std. Error
b	0.392	0.014
δ	0.356	0.071
μ	14.883	0.032
σ^2	0.209	0.008
e	0.051	0.007
k_1	-44.991	4.365
k_2	45.060	3.757
k_3	4.456	1.058
k_4	-0.433	0.055
k_5	-0.079	0.013
k_6	0.008	0.001
k_7	-0.0002	0.00001

Table 7: Counterfactual consumption equivalence of age bans with and without credit markets

Panel A: Baseline has no credit market	
Counterfactual scenario	π
Minimum age of marriage is 16	-0.14%
Minimum age of marriage is 18	-0.18%
Panel B: Baseline has perfect credit market	
Counterfactual scenario	π
Minimum age of marriage is 16	-0.03%
Minimum age of marriage is 18	-0.04%

Notes: Last column presents the share π of consumption that a household in the baseline scenario requires to be indifferent to counterfactual scenario. The equivalent variation π solves $\sum_{k=1}^{K}\sum_{t=14}^{T}\delta^{t-1}\frac{((1+\pi)c_{B,t})^{1-b}}{1-b} + \sum_{k=1}^{K}\sum_{t=14}^{T}\delta^{t-1}m_{B,t}\cdot\xi_t = \sum_{k=1}^{K}\sum_{t=14}^{T}\delta^{t-1}\frac{c_{CF,t}^{1-b}}{1-b} + \sum_{k=1}^{K}\sum_{t=14}^{T}\delta^{t-1}m_{CF,t}\cdot\xi_t$.

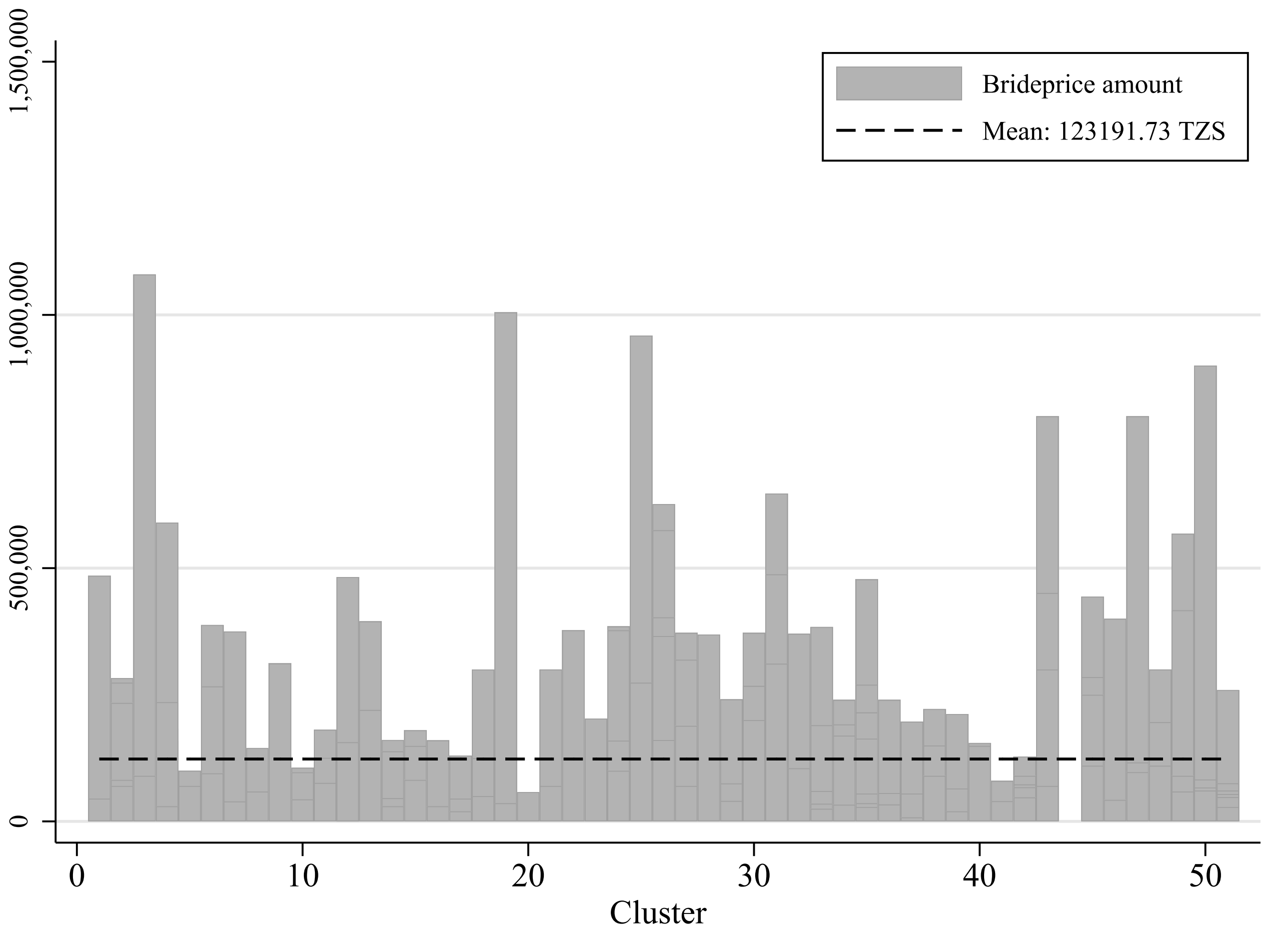
Table 8: Counterfactual consumption equivalence – cash transfer programs

	Individual transfer (Thousands of TZS)	Total cost per capita (Thousands of TZS)	π
Panel A: Reduces child marriage by 20%			
Conditional transfer	3.76	16.97	0.12%
Unconditional transfer	67.12	335.62	3.35%
Transfer to bottom 25% of income	74.76	93.95	0.88%
Panel B: Reduces child marriage by 50%			
	Individual transfer (Thousands of TZS)	Total cost per capita (Thousands of TZS)	π
Conditional transfer	10.65	50.25	0.41%
Unconditional transfer	209.78	1048.92	10.72%
Transfer to bottom 25% of income	227.12	285.42	2.78%
Panel C: Reduces child marriage by 100%			
	Individual transfer (Thousands of TZS)	Total cost per capita (Thousands of TZS)	π
Conditional transfer	35.11	175.39	1.60%
Unconditional transfer	880.74	4403.71	48.22%
Transfer to bottom 25% of income	880.74	1106.8	11.28%

Notes: Average annual income is 3243.41 thousands of Tanzanian shillings. Last column presents the share π of consumption that a household in the baseline scenario requires to be indifferent to the counterfactual scenario. The equivalent variation π solves $\sum_{k=1}^{K}\sum_{t=14}^{T}\delta^{t-1}\frac{((1+\pi)c_{B,t})^{1-b}}{1-b}+\sum_{k=1}^{K}\sum_{t=14}^{T}\delta^{t-1}m_{B,t}\cdot\xi_t=\sum_{k=1}^{K}\sum_{t=14}^{T}\delta^{t-1}\frac{c_{CF,t}^{1-b}}{1-b}+\sum_{k=1}^{K}\sum_{t=14}^{T}\delta^{t-1}m_{CF,t}\cdot\xi_t$.

Appendix Figures

Figure A1: Variation in bride price amount, by cluster



Notes: Sample of respondents with non-missing information for the age of marriage and rainfall shocks at the ages 17-18. Source: Kagera Health Development Survey, 2004-2010.

Figure A2: Average bride price amounts, 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 age at marriage is defined between 14 to 33. 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), with controls for parental assets (specification #2), with wedding year dummies (specification #3) and adding dummies for parental education (specification #4). Source: Kagera Health Development Survey 2004-2010.

Appendix Tables

Table A1: Summary statistics, full sample

Panel A: Marriage's characteristics	*Mean* (1)	*Std. Dev* (2)	*Obs* (3)
Age at marriage	21.96	4.19	1,246
Marriages by 15	0.04	0.19	1,246
Marriages by 18	0.20	0.40	1,246
Married between 15 and 18 years old	0.17	0.38	1,246
Married between 16 and 18 years old	0.16	0.36	1,246
Married between 17 and 18 years old	0.12	0.32	1,246
Married between 19 and 20 years old	0.18	0.39	1,246
Married between 21 and 22 years old	0.20	0.40	1,246
Married between 23 and 24 years old	0.17	0.38	1,246
Panel B: Demographic characteristics			
Urban	0.24	0.43	1,246
Bad house (PCA)	0.40	1.26	1,246
Mother no edu	0.04	0.11	1,246
Mother primary edu	0.91	0.16	1,246
Mother secondary edu and above	0.05	0.12	1,246
Father no edu	0.03	0.10	1,246
Father primary edu	0.87	0.21	1,246
Father secondary edu and above	0.10	0.18	1,246
Panel C: Rainfall shocks			
Rainfall shock, age 8-18	96.08	23.23	1,069
Rainfall shock, age 15-18	100.34	40.30	1,218
Rainfall shock, age 16-18	103.18	45.53	1,231
Rainfall shock, age 17-18	106.37	59.83	1,246
Rainfall shock, age 15	93.79	89.16	1,221
Rainfall shock, age 16	98.57	89.27	1,231
Rainfall shock, age 17	105.44	91.92	1,246
Rainfall shock, age 18	107.31	96.13	1,246

Notes: Sample of respondents with non-missing information for the age of marriage and rainfall shocks at ages 17-18. Rainfall shocks are computed as 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) at each age of the respondents. The type of dwelling is described by the construction material of the floor, the roof and outside walls of respondent's household. Bad house (PCA) is the principal components of wall, floor and roof made by mud, bamboo tree or earth (compared to those made by iron, stone or cement). Source: Kagera Health Development Survey 2004-2010 for Panels A and B and NASA Langley Research Center for rainfall measures.

Table A2: Child marriage and rainfall shocks, controls

Dependent variable: *If married:*	By 18		between 15-18		between 16-18		between 17-18	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Rainfall shocks by 18	0.470**	0.464*						
	(0.142)	(0.157)						
	[0.041]	[0.053]						
Rainfall shock, age 15-18			0.226**					
			(0.061)					
			[0.018]					
Rainfall shock, age 16-18					0.131			
					(0.059)			
					[0.127]			
Rainfall shock, age 17-18							0.132***	
							(0.046)	
							[0.002]	
Rainfall shock, age 15				0.025				
				(0.018)				
				[0.189]				
Rainfall shock, age 16				0.037		0.018		
				(0.044)		(0.043)		
				[0.457]		[0.770]		
Rainfall shock, age 17				0.072*		0.056		0.072**
				(0.033)		(0.031)		(0.026)
				[0.090]		[0.170]		[0.012]
Rainfall shock, age 18				0.083*		0.060		0.061*
				(0.041)		(0.038)		(0.029)
				[0.084]		[0.123]		[0.059]
Urban		-0.067	-0.069	-0.067	-0.045	-0.044	-0.061	-0.061
		(0.037)	(0.059)	(0.058)	(0.057)	(0.056)	(0.037)	(0.037)
		[0.156]	[0.295]	[0.297]	[0.473]	[0.498]	[0.217]	[0.209]
Bad House (PCA)		-0.012	-0.003	-0.002	0.005	0.005	0.003	0.003
		(0.011)	(0.010)	(0.009)	(0.007)	(0.007)	(0.010)	(0.010)
		[0.340]	[0.752]	[0.832]	[0.564]	[0.508]	[0.760]	[0.758]
Mother Primary Edu		-0.181	-0.199	-0.198	-0.249	-0.245	-0.140	-0.140
		(0.103)	(0.092)	(0.090)	(0.085)	(0.083)	(0.092)	(0.093)
		[0.172]	[0.160]	[0.164]	[0.184]	[0.182]	[0.627]	[0.627]
Mother Secondary Edu and above		-0.399***	-0.283*	-0.274*	-0.305*	-0.294	-0.193	-0.192
		(0.071)	(0.100)	(0.097)	(0.094)	(0.091)	(0.129)	(0.129)
		[0.002]	[0.070]	[0.051]	[0.082]	[0.104]	[0.518]	[0.523]
Father Primary Edu		-0.010	-0.016	-0.028	0.103	0.095	0.002	0.002
		(0.089)	(0.115)	(0.118)	(0.160)	(0.169)	(0.159)	(0.159)
		[0.889]	[0.910]	[0.844]	[0.600]	[0.693]	[0.994]	[0.992]
Father Secondary Edu and above		-0.026	-0.053	-0.072	0.071	0.060	-0.005	-0.005
		(0.095)	(0.116)	(0.123)	(0.162)	(0.170)	(0.159)	(0.158)
		[0.799]	[0.699]	[0.615]	[0.660]	[0.727]	[0.982]	[0.980]
Grid Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year of Birth Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mean Dependent Variable	0.300	0.300	0.260	0.260	0.240	0.240	0.180	0.180
R^2	0.055	0.093	0.093	0.095	0.087	0.088	0.089	0.089
Observations	674	672	725	725	730	730	735	735

Notes: OLS regressions. Sample of women with non-missing information on the age of marriage and rainfall shocks at ages 17-18. Robust standard errors in parentheses, clustered at the grid level. Wild bootstrap (5000 repetitions) p-values in square brackets with corresponding *** 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 2, include dummies for mother and father highest level of education (primary education and secondary/tertiary education, with no education as omitted category), the principal component analysis for inadequate house and a dummy indicating urban areas. Source: Kagera Health Development Survey 2004-2010.

Table A3: Child marriage and rainfall shocks, sample of men

Dependent variable: *If married:*	By 18		between 15-18		between 16-18		between 17-18	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Rainfall shocks by 18	-0.100	-0.115						
	(0.102)	(0.104)						
	[0.402]	[0.402]						
Rainfall shock, age 15-18			-0.051	-0.004				
			(0.037)	(0.016)				
			[0.314]	[0.877]				
Rainfall shock, age 16-18					-0.046			
					(0.027)			
					[0.105]			
Rainfall shock, age 17-18							-0.023	
							(0.013)	
							[0.180]	
Rainfall shock, age 19-23								
Rainfall shock, age 16				-0.008		-0.010		
				(0.011)		(0.011)		
				[0.473]		[0.340]		
Rainfall shock, age 17				-0.022		-0.020*		-0.011
				(0.014)		(0.012)		(0.009)
				[0.164]		[0.080]		[0.297]
Rainfall shock, age 18				-0.016		-0.015		-0.012
				(0.010)		(0.010)		(0.008)
				[0.215]		[0.230]		[0.221]
Grid Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year of Birth Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mean Dependent Variable	0.050	0.050	0.030	0.030	0.030	0.030	0.030	0.030
R^2	0.092	0.122	0.128	0.130	0.131	0.131	0.134	0.134
Observations	395	395	493	493	501	501	511	511

Notes: OLS regressions. Sample of men with non-missing information for the age of marriage and rainfall shocks at ages 17-18. Robust standard errors in parentheses, clustered at the grid level. Wild bootstrap (5000 repetitions) p-values in square brackets with corresponding *** 1% , ** 5% , * 10% significance. Constant not displayed. Rainfall shocks are computed as 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) at each age of the respondents. All the coefficients (standard errors) are multiplied by 100. Controls, as described in table 2, include dummies for mother and father highest level of education (primary education and secondary/tertiary education, with no education as omitted category), the principal component analysis for inadequate house and a dummy indicating urban areas. Source: Kagera Health Development Survey 2004-2010.

Table A4: Main reason for migration by gender

Panel A: Migration		
	Females	*Males*
Migration(%)	0.58	0.41
Observations	735	511
Panel B: Reason for migration		
Marriage	31.84	3.52
Job	2.59	10.18
Other family problems	3.95	6.46
Death of parents	3.81	3.52
Find land	0.68	3.91
Schooling	1.50	1.37
Following inheritage	0.27	2.74
Live healthier environment	0.95	0.20
Divorced	0.54	0.20
Illness of HH member	0.54	0.20
Political/Economics problems	0.41	0.20
Life is better here	0.27	0.00
Widowhood	0.14	0.20
Natural disaster	0.00	0.20
Other	5.99	4.70
Missing	46.53	62.43
Observations	735	511
Panel C: T-test - Marriage is the reason for migrating		
	Migration for marriage	
Marriage > 18	0.286	0.037
Marriage ≤ 18	0.393	0.000
p-value	0.004	0.384
Observations	735	511

Notes: Sample of respondents with non-missing information on the age of marriage and rainfall shocks at ages of 17-18. Migration in Panel A is equal to 1 if the individual moved to another village at least once since birth up until 2010. In Panel C, we report the p-value of the difference between migration for marriage for individuals $<$ or $\geq$ of 18.

Table A5: Child marriage and rainfall shocks, heterogeneity effects

	By bride price of neighboring women				*By household's composition*			
Dependent variable: *If married:*	*By 18* (1)	*between 15-18* (2)	*between 16-18* (3)	*between 17-18* (4)	*By 18* (5)	*between 15-18* (6)	*between 16-18* (7)	*between 17-18* (8)
Rainfall shock. age 8-18* Village bride price during youth	0.001							
	(0.002)							
Rainfall shock. age 15-18* Village bride price during youth		0.001*						
		(0.000)						
Rainfall shock. age 16-18* Village bride price during youth			0.001					
			(0.001)					
Rainfall shock. age 17-18* Village bride price during youth				0.001*				
				(0.000)				
Rainfall shock, age 8-18* # of sisters during youth					-0.085			
					(0.061)			
Rainfall shock, age 8-18* # of brothers during youth					0.051			
					(0.079)			
Rainfall shock, age 15-18* # of sisters during youth						-0.089**		
						(0.034)		
Rainfall shock, age 15-18* # of brothers during youth						0.053		
						(0.030)		
Rainfall shock, age 16-18* # of sisters during youth							-0.078*	
							(0.039)	
Rainfall shock, age 16-18* # of brothers during youth							0.061	
							(0.038)	
Rainfall shock, age 17-18* # of sisters during youth								-0.042***
								(0.009)
Rainfall shock, age 17-18* # of brothers during youth								-0.001
								(0.008)
Rainfall shock, age 8-18	0.382*				0.581**			
	(0.191)				(0.211)			
Rainfall shock, age 15-18		0.130				0.322***		
		(0.078)				(0.068)		
Rainfall shock, age 16-18			0.035				0.149*	
			(0.068)				(0.073)	
Rainfall shock, age 17-18				0.097*				0.193**
				(0.044)				(0.066)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Grid Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year of Birth Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mean Dependent Variable	0.320	0.280	0.260	0.200	0.430	0.370	0.340	0.260
R^2	0.092	0.108	0.099	0.102	0.203	0.207	0.196	0.177
Observations	606	636	640	644	457	501	505	509

Notes: OLS regressions. Sample of women with non-missing information for the age of marriage and rainfall shocks at ages 17-18. *** 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 2, include dummies for mother and father highest level of education (primary education and secondary/tertiary education, with no education as omitted category), the principal component analysis for inadequate house and a dummy indicating urban areas. In cols.1-4 we also control for household consumption per capita and the interaction between household consumption per capita and rainfall shocks at 8-18, 15-18, 16-18, 17-18 respectively, and average village bride price at age 8-18. The variable village average bride price is the average bride price amount received by women living in the same village as the respondent married when the respondent was 8-18. In cols. 5-8 we control for household size in the wave and the number of brothers and sisters when the respondent was 8-18. The variables number of brothers and number of sisters during youth is the average number of brothers or sisters when the respondent was 8-18. Source: Kagera Health Development Survey 2004-2010.

Table A6: Probability of marriage at age 19-24

	Females						Males					
Dependent variable: If married:	*between 19-20*		*between 21-22*		*between 23-24*		*between 19-20*		*between 21-22*		*between 23-24*	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Rainfall shock, age 19-20	-0.012						0.026					
	(0.054)						(0.046)					
Rainfall shock, age 21-22			-0.012						-0.006			
			(0.051)						(0.058)			
Rainfall shock, age 23-24					-0.031						0.062	
					(0.029)						(0.082)	
Rainfall shock, age 19		-0.012						0.005				
		(0.039)						(0.034)				
Rainfall shock, age 20		-0.000						0.019				
		(0.026)						(0.032)				
Rainfall shock, age 21				0.017						0.005		
				(0.033)						(0.039)		
Rainfall shock, age 22				-0.025						-0.012		
				(0.033)						(0.034)		
Rainfall shock, age 23						-0.022						0.058
						(0.023)						(0.046)
Rainfall shock, age 24						-0.009						0.007
						(0.019)						(0.056)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Grid Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year of Birth Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mean Dependent Variable	0.240	0.240	0.200	0.200	0.130	0.130	0.090	0.090	0.210	0.210	0.230	0.230
R^2	0.139	0.139	0.143	0.145	0.121	0.122	0.230	0.230	0.210	0.210	0.185	0.187
Observations	706	706	681	681	594	594	498	498	496	496	478	478

Notes: OLS regressions. Sample of respondents with non-missing information for the age of marriage and rainfall shocks at ages 17-18. Robust standard errors in parentheses, clustered at the grid 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 2, include dummies for mother and father highest level of education (primary education and secondary/tertiary education, with no education as omitted category), a dummy for respondents living in inadequate house, a dummy indicating urban areas. Source: Kagera Health Development Survey 2004-2010.

Table A7: Probability of marriage by age 13-15

	Females					Males	
Dependent variable: *If married:*	*between 13-14*			*between 14-15*		*between 14-15*	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Rainfall shock, age 15-18	-0.028						
	(0.036)						
Rainfall shock, age 16-18		-0.019		0.037		0.000	
		(0.022)		(0.038)		(0.002)	
Rainfall shock, age 17-18			-0.022		0.012		-0.003
			(0.019)		(0.028)		(0.003)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Grid Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year of Birth Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mean Dependent Variable	0.020	0.020	0.020	0.030	0.030	0.000	0.000
R^2	0.109	0.108	0.109	0.049	0.047	0.128	0.128
Observations	725	730	735	730	735	501	511

Notes: OLS regressions. Sample of Sample of respondents with non-missing values for the age at marriage and rainfall shocks at 17-18. Robust standard errors in parentheses, clustered at the grid 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 2, include dummies for mother and father highest level of education (primary education and secondary/tertiary education, with no education as omitted category), a dummy for respondents living in inadequate house, a dummy indicating urban areas. Source: Kagera Health Development Survey 2004-2010.

Appendix A: Description of the empirical samples

In this section, we describe the two main samples we used in our empirical analysis. To test the effect of rainfall shocks on consumption (Table 3), we exploit all the six waves of the KHDS panel dataset. We have 8,293 individuals with non-missing information on consumption in last 12 months. To test the effect of rainfall shocks on early marriage we used a cross-sectional dataset only keeping the latest wave in which the respondent has been surveyed and in which information related to her age at marriage has been elicited. Indeed, the information on the age of marriage does not change across waves. We then keep individuals with non-missing information for the age at marriage and rainfall shocks at ages 17-18 and end up with a dataset of 1,246 observations (735 women and 511 men). This is the sample we used in all the other tables and figures. Looking at our main Table 4, we note that the number of observations decreases when analyzing the effect of shocks in different years in a women's life cycle. This is because among the 735 women for which we have data on rainfall shock at 17-18 years, we do not observe their cluster of residence for 5 of them when they were 16 (getting 730 observations) and for 10 of them when they were 15 (725 observations) because they migrated multiple times but we do not know the year of migration (see footnote 8 in the main text). The same argument applies when analyzing rainfall shocks by 18 in columns 1 and 2 of Table 4 or Table A3. In Tables 5, A5 and A6, the lower number of observations is due to missing information either in the dependent variable or in the rainfall shocks, for the same reason mentioned above.