On the Timing of Marriage, Cattle, and Shocks

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I. Introduction

In developing countries financial markets are often absent or incomplete. The absence of financial markets is particularly severe in rural areas, where farmers face liquidity constraints and cannot insure against a bad harvest or loss of livestock. Whereas a bad harvest has immediate consequences for farmers' welfare, the consequences of loss of livestock are longer lasting. Without draft power from cattle, households can only produce using the hoe, which yields little income. Loss of livestock, therefore, leads a household to being stuck in poverty for a considerable period of time (see Carter and Zimmerman 2000).

In the absence of formal financial institutions a large range of nonmarket solutions has become available to insure households against negative shocks and to allow them to smooth consumption over time. Examples of such nonmarket solutions are food-sharing arrangements in which a household confronted with a negative idiosyncratic shock gets food from other households and labor-sharing arrangements whereby other farmers take care of the land of someone who is temporarily unable to do so. See Rosenzweig (2001) for a review of the literature on informal insurance arrangements in low-income countries.

This paper contributes to the literature on shocks and coping mechanisms.

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Much of this literature deals with the accumulation and disposal of buffer stocks for self-insurance (Rosenzweig and Wolpin 1993; Fafchamps, Udry, and Czukas 1998; Kinsey, Burger, and Gunning 1998), while related literature focuses on the formation of networks within which risks are shared. For instance, De Weerdt and Dercon (2006) show that households form networks within a village that insulate them from income shocks; Rosenzweig (1988) and Rosenzweig and Stark (1989) demonstrate that family links outside the household perform a similar function. This paper contributes to this literature by demonstrating that the timing at which risk-sharing networks are formed—in this case through marriage—is responsive to exposure to shocks.

The focus of this paper is on the timing of marriage as an alternative institution for insurance against the loss of livestock. Marriage may act as a nonmarket insurance because the marriages considered here involve bride wealth payments. In the empirical analyses, we consider rural Zimbabwe, where these payments are made by (the family of) the groom to the bride's family. Bride wealth consists of a substantial number of cattle of which a considerable fraction is paid at the time of marriage. An unmarried daughter thus represents access to livestock, and her marriage may be considered an asset that can be cashed in during times of adversity. Because of bride wealth payments, marriages should be considered a contract between families rather than between individuals. The choice of the spouse, however, is typically not a household decision but an individual decision. Therefore, we do not focus on the choice of spouses but consider the timing of marriage.

The bride's family can use the cattle obtained through bride wealth to increase agricultural production and as buffer stock. The timing of a marriage is determined by both the individual and her family. The expectation is that the marriage decision of a daughter is more likely to be a household decision in poor households than in wealthier households. In the empirical analyses, we investigate to what degree the timing of marriage of young women can be explained by economic conditions of the households from which they originate.

There are many aspects to how shocks affect marriage. It is particularly important to distinguish between correlated shocks, such as those induced by a lack of rainfall, and idiosyncratic shocks because of the theft or death of cattle, as each can have quite different consequences for household behavior. Unlike idiosyncratic shocks, correlated shocks may have equilibrium effects on the marriage market. If after a year of low rainfall households press their daughters to marry, they may equally prefer their sons not to marry. After a year of low rainfall the total number of marriages may therefore decline. Fewer marriages may also be expected because the family of the groom, who customarily has to pay for the wedding ceremony, may have difficulty finding the required resources shortly after a drought. On the other hand, families with cattle may want to press their sons into marriage following a drought in an attempt to pass on the risk of the nonsurvival of the (weakened) cattle to the family of the bride. Consequently, the effect of a covariate shock on marriage is an empirical matter. A drought may also have consequences on the amount of bride wealth. We return to these issues in our theoretical model, where we will distinguish between correlated and idiosyncratic shocks. The theoretical model serves as a starting point for our empirical analyses where we consider the timing of a daughter's marriage and the amount of bride wealth while distinguishing between idiosyncratic and correlated shocks.

The composition of the population of unmarried women in a particular year depends on marriages in previous years. For this reason a dynamic model is required to empirically analyze the timing of a marriage. If in a particular year many women from poor households marry, then in the following year the population of unmarried women shifts toward women from richer households. To account for this we use hazard rates. We allow the transition rate from unmarried to married (the marriage rate) to depend on both individual, household, and environmental characteristics, on the elapsed duration of being unmarried (age), and on unobserved determinants. To separate idiosyncratic shocks from household-specific wealth levels and correlated shocks, we use a dynamic model for household wealth accumulation. Finally, we also perform empirical analyses on the size of bride wealth payments. In this analysis, we distinguish between immediate and long-term bride wealth payments. This provides additional insight in the bargaining process between the families of the bride and groom.

We use data from an annual panel survey held under a group of resettlement farmers in Zimbabwe, which started in 1982. The earlier surveys only contained household-level variables, but from 1994 onward detailed information on all members was collected. We use the subset of the data that starts in 1994, which includes approximately 400 households. The data on household members allow us to construct subsamples of unmarried daughters with information on the marriage decision, individual characteristics, and some measures of household wealth. Since the data we use in the empirical analyses deal with farmers, in the remainder of the paper we restrict our discussions to farmers and rural areas. It should be noted that our data describe the period before the start of the political crisis in Zimbabwe.

The paper is organized as follows. In Section II the institutions of marriage in rural Zimbabwe are considered in more detail. Section III presents both the theoretical and empirical model. Section IV describes the data. The estimation results and sensitivity analyses are presented in Section V. Section VI concludes.

II. Marriage in Zimbabwe

Marriage in Zimbabwe is characterized by duality, as the choice of one's spouse is left to the individuals concerned while the marriage itself is a contract between families. Zimbabwean families related through marriage typically share resources in an effort to deal with risks. Families prefer to spread the net of affinal relations by marrying into different families. Marriages over a long distance or with someone with a job in town are considered with favor as these mitigate the impact of local weather shocks (see Rosenzweig 1988; Rosenzweig and Stark 1989).

Bourdillon (1987) and Holleman (1952) provide extensive descriptions of Shona marriage customs. Although their description might be dated, Goebel (2006) stresses that it is still accurate for current marriage practices in rural areas. Zimbabwean marriages include bride wealth payments, which are transfers from the family of the groom to the family of the bride.[1] Bride wealth in Zimbabwe consists of two distinct payments, which are referred to as *rutsambo* and *danga*. *Rutsambo* is associated with sexual rights to the woman, and after its payment the woman is allowed to move to her husband's household. *Danga* is associated with rights over children born to the woman. Cattle are the main body of the bride wealth. On average, eight to nine head of cattle are demanded as bride wealth (Dekker and Hoogeveen 2002).

Marriages usually take place after the harvest (in June/July) and before the start of the next rainy season (in November). At the time of marriage a substantial part of *danga* is paid, but the bulk remains outstanding. Full payment is extended over a long period of time. In figure 1 we show how the fraction of marriages where all bride wealth payments have been made evolves over the duration of the marriage. For less than 10% of the marriages, bride wealth payments are completed in the first few years after the marriage. For over 80% of the marriages some part of the bride wealth is still outstanding after 25 years of marriage. The large drop occurs around 30 years of marriage, which implies that for most marriages the final bride wealth payments are made between 28 to 35 years of marriage. Delayed payment has advantages for both the family of the bride and the family of the groom. For the son-in-law, delayed payment implies that he can pay when he has the means to do so. Moreover, he can make sure that his wife is childbearing. Being barren is a valuable reason to undo a marriage. After a divorce or if the wife dies

[1] The expenditures of the actual wedding are paid by the family of the groom.

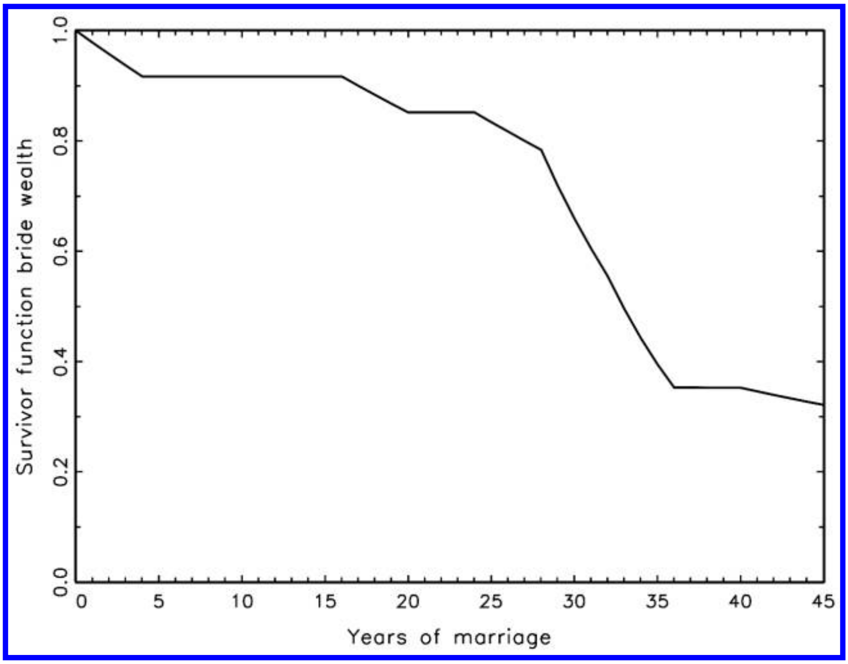

Figure 1. The fraction of marriages where all bride wealth payments are made at a given number of years of marriage. This figure is based on a supplement of the survey held in 1995.

without giving birth to many children, the husband can claim back (part of) the bride wealth. On the other hand, as long as the bride wealth is not completely paid, the family of the bride can ask the groom for favors in the form of services and gifts. This is illustrated by a Zimbabwean proverb saying, "A son-in-law is like a fruit tree: one never finishes eating from it." Furthermore, delayed payments secure that a household which loses its cattle still has access to some assets (see Dekker and Hoogeveen 2002). Therefore, even if the son-in-law is in a position to pay all bride wealth upon marriage, it is considered a denial of the marriage bond between the families involved to actually do so.

The optimal timing of marriage is evident. Unless the household is very wealthy, sons should marry late and daughters early. Late marriage of a son has several advantages. The son remains productive in the family's agricultural activities, and the loss of draft power is postponed. After the marriage of a daughter the previously (cattle) poor family is able to experience a period of high productivity before the marriage of a son is supported. This period of high productivity can be used to accumulate more cattle and to grow out of initial poverty. Another reason why daughters should marry young is that the amount of bride wealth decreases with age, which reflects that young women are likely to give birth to more children (e.g., Holleman 1952). Our data confirm the existence of a negative relation between age of marriage and amount of bride wealth. National data are consistent with this pattern; the marriage age of men is much higher than that of women (see Central Statistical Office 1995). The median age at first marriage for men is 25 years, compared to 19 years for women. Only 11% of the men are married by the age of 20, compared to 62% of the women.

III. Model

In this section we present our theoretical and empirical model. The theoretical model is a dynamic model of household behavior. Its purpose is to illustrate the effects of wealth, household size, and shocks on the household's marriage decision. This model serves as starting point for the empirical analysis.

A. Theoretical Model

We construct a discrete-time dynamic-programming model taking into account credit constraints, risk, and uncertainty (see, e.g., Rosenzweig and Wolpin 1993; chap. 8 in Bardhan and Udry 1999). A key decision in each period is whether or not a daughter should marry. If a household decides that a daughter should marry, it gains cattle immediately but loses labor input and the possibility of dealing with future negative shocks. We ignore alternative consumption-smoothing or risk-sharing mechanisms apart from marriage of daughters and the accumulation of cattle.

The household's agricultural production depends mainly on three sources, the input of labor, the availability of cattle, and the amount of rainfall.[2] Let q_t denote the production of crop in year t, which follows the production function $f(B_t, M_t, R_t)$, where B_t is the head of cattle owned by the household, M_t is the number of (unmarried) daughters, and R_t is (local) rainfall. The production function is increasing in its arguments. Because we are interested in the (marriage) behavior of daughters, we only include the number of daughters in the production function, thereby assuming the number of sons fixed. In Zimbabwe, due to the heavy loam soils, at least two head of cattle are required for preparing the land for sowing; therefore, we impose the constraint $q_t = 0$ if $B_t < 2$.

A household can consume c_t agricultural production or save it. Saving is done by expanding the stock of cattle. The amount of consumption is decided after the household learns the production level q_t. Because of borrowing con-

[2] For the resettlement farmers studied in the empirical analyses the availability of land does not seem a binding constraint, and until 1992 heads of households were not allowed to work off farm.

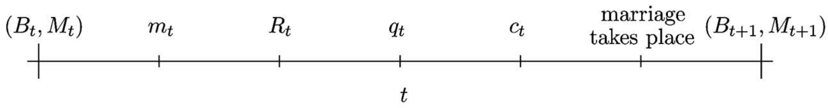

Figure 2. Timing of events within a time period

straints, households can never consume more than the sum of their production and stock of cattle, that is, $c_t \leq q_t + B_t$ (the price of cattle in crops is constant over time and normalized to 1). The marriage decision is made at the beginning of the period (before producing), but the marriage occurs at the end of the period (after consuming). The timing in our model is consistent with the order in which events are observed in rural Zimbabwe (see Sec. II). Figure 2 shows the timing of shocks and household decision making within a time period. We allow at most one daughter to marry each year; the variable m_t takes the value one if a daughter marries in period t and zero otherwise. The number of unmarried daughters in the household evolves according to $M_{t+1} = M_t - m_t$ (under the restriction $M_{t+1} \geq 0$).

Household wealth evolves over time according to the law of motion

$$B_{t+1} = \delta B_t + q_t - c_t + p_t m_t + \omega_t. \tag{1}$$

The parameter δ represents the growth rate of cattle, which is caused by strengthening of cattle, birth, death, aging, and so on. The parameter p_t denotes the amount of bride wealth associated with marrying off a daughter. For simplicity, we only take into account the initial payment and ignore subsequent payments in later periods. The amount of bride wealth is decided on the marriage market, so it can change over time due to covariate (rainfall) shocks. We return to this below. Cattle are subject to several (idiosyncratic) risks, denoted by ω_t, such as theft. The absence of financial markets implies the restriction $B_t \geq 0$.

A household exists for T periods and maximizes the expected present value of lifetime utility

$$U_t = E_t\left[\sum_{\tau=t}^{T} (1 + r)^{t-\tau} v(c_t)\right].$$

The instantaneous utility of a household is given by $v(c_t)$, which is increasing in c_t. We assume that the utility of consumption does not depend on household size. However, in a smaller household the utility of a given consumption level may be higher, because consumption is shared by fewer people. This might be an additional benefit of a daughter's marriage. Future utility is discounted at rate r.

The state variables cattle B_t and unmarried daughters M_t can be considered

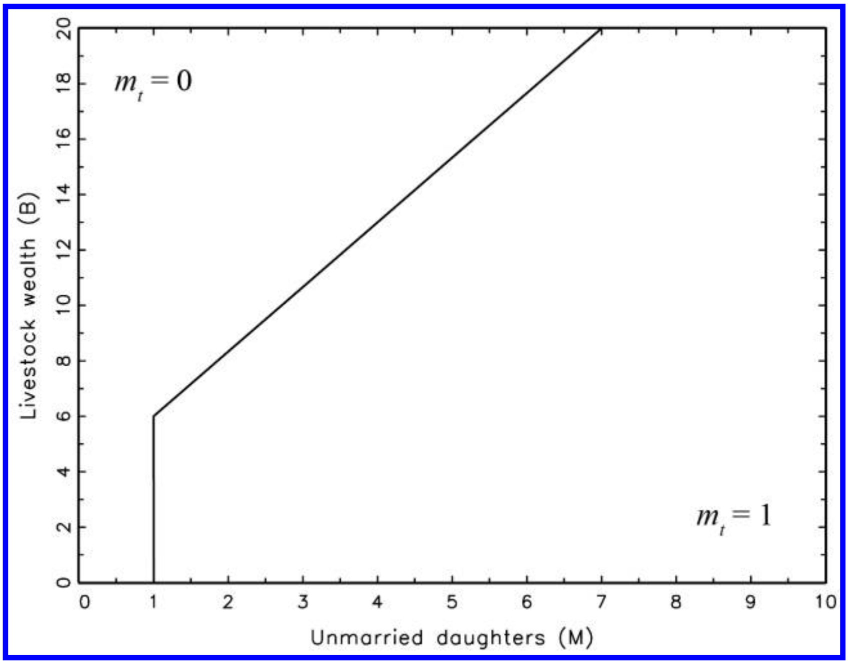

Figure 3. The marriage decision of households with M_t unmarried daughters and B_t livestock wealth. The area $m_t = 1$ describes combinations (M_t, B_t) for which it is optimal for the household to marry off a daughter. The amount of bride wealth is independent of the amount of rainfall.

the household's assets. The choice variables are c_t and m_t. In the context of assets, marriages are used for portfolio diversification. Both the idiosyncratic (wealth) shocks ω_t and rainfall R_t are assumed to be independent and identically distributed over time. Because we have not yet incorporated the marriage market in our model, both shocks have similar effects on household behavior. Below, we consider possible equilibrium effects on the marriage market of rainfall shocks. We solve the model backwards following Keane and Wolpin (1994), by approximating the value function $U_t(B_t, M_t)$ for each value of $M_t = 0, 1, 2, \ldots$ as a higher order polynomial in B_t. As the marriage decision is made at the beginning of the period, the optimal m_t only depends on the state variables B_t and M_t. The optimal decision of the household is illustrated in figure 3. In this figure the optimal marriage strategy is depicted in the (M_t, B_t) plane. The region denoted by $m_t = 0$ contains the combinations of cows and daughters for which it is optimal not to let daughters marry, while the opposite holds for the region indicated by $m_t = 1$. In appendix A we provide the specification and values of the parameters that generated this figure, but the general picture is not very sensitive to the choice of the functional forms and parameter values.

The figure shows that a daughter should marry if the number of daughters is high relative to livestock wealth. In the current specification, both idiosyncratic (wealth) shocks and rainfall shocks affect the number of cattle owned by the household (one period later). Most households do not own a sufficient number of cattle to deal with the consequences of negative shocks. When such a vulnerable household is hit by a negative shock (in year $t - 1$), the household might be pushed from the $m_t = 0$ area to the $m_t = 1$ area. In that case the household exercises the "option value" of an unmarried daughter to increase its herd size.

So far, we imposed the constraint that the amount of bride wealth is fixed. This might be too strong an assumption, and, therefore, we investigate two extensions of the model. First, the amount of bride wealth might be decreasing in the age at which a daughter gets married. The amount of bride wealth is a reflection of the ability of women to bear children. Second, rainfall shocks are spatially correlated and may, therefore, have equilibrium effects on the marriage market. This may imply that after a bad harvest the amount of bride wealth is lower.

Let us first focus on making bride wealth payments dependent on the age at marriage. We can no longer use the number of unmarried daughters as a state variable but should instead keep track of the ages of all unmarried daughters at each moment in time. This dimensionality problem makes the model practically unsolvable. Therefore, we make a simplifying assumption that there are only three age categories and that women move stochastically between these groups. We maintain the assumption that each year at most one daughter in a household can marry.

Let M_t^y denote the number of daughters in the youngest age category in the household in year t. The bride wealth payments associated with the marriage of a woman in this youngest age group is p^y. Each year each woman in this age category has a probability λ of moving to the middle age group. The number of daughters in this middle age category equals M_t^m. If a daughter from this middle age group gets married, the amount of bride wealth is p^m, which is lower than p^y. Again with probability λ a daughter from the middle age group enters the oldest age group. The variable M_t^o denotes the number of daughters in this oldest age category. If a woman from this age group marries, the bride wealth payments equal p^o, which is less than p^m.

The first implication of this specification is that a household will never marry off a daughter in the oldest age group if there are daughters present in one of the other age categories. The main reason for this is that girls in the oldest age group are not exposed to the risk of losing value if they do not marry, while the daughters in the other age groups face this risk. We should thus interpret the oldest age group as women who will most likely never marry, for example, because they become too old to give birth.

It is more interesting to focus on daughters in the youngest and the middle age category. The risk that women lose bride wealth value because they get older causes additional opportunity costs of not marrying. This implies that these groups are more likely to get married. The decreasing pattern in bride wealth payments thus causes daughters to marry at younger ages. This effect is particularly large if λ is high and reductions in bride wealth between age groups are large.

It is interesting to ask which daughter a household prefers to marry after a bad shock if the household has a daughter in both the youngest and the middle age group. The answer is ambiguous; the optimal choice is mainly determined by the rate at which girls move to older age groups and the reductions in bride wealth over age. Let us assume that the reduction in bride wealth payment is larger when moving from the middle to the oldest age group than when moving from the youngest to the middle age group, that is, $p^m - p^o > p^y - p^m$. In this case the household prefers to marry the daughter in the middle age group over the daughter in the youngest age group if λ is large.[3] However, if λ is small the household prefers to marry off the youngest daughter.[4]

The second extension we consider is that rainfall is spatially correlated and can have equilibrium effects. After a period of low rainfall, many households want a daughter to marry, while not many households are willing to pay bride wealth for sons getting married. This reduces the amount of bride wealth paid at marriage. We try to mimic equilibrium effects by allowing the amount of bride wealth p_t to depend on the rainfall one period earlier R_{t-1}. In figure 4 we again show the optimal marriage decision in the (M_t, B_t) plane for different levels of rainfall R_{t-1}. It is clear that for a given B_t households are more likely to marry off a daughter in periods of high rainfall, that is, the $m_t = 1$ area is largest for $R_{t-1} = 0.9$. However, low rainfall R_{t-1} also reduces the amount of livestock B_t one period later. Therefore, the effect of low rainfall on marriage remains an empirical matter.

3 Consider the extreme case that λ equals one, implying that all girls move to an older age group every year. The daughter in the middle age group loses more value if she is not married off than the daughter in the youngest age group.

4 If λ is zero, girls do not move to older age groups. Marrying off the youngest daughter provides more cattle, and thus more future production, than marrying off the older daughter. The opportunity costs of staying unmarried for another period are highest for the youngest daughter in the household.

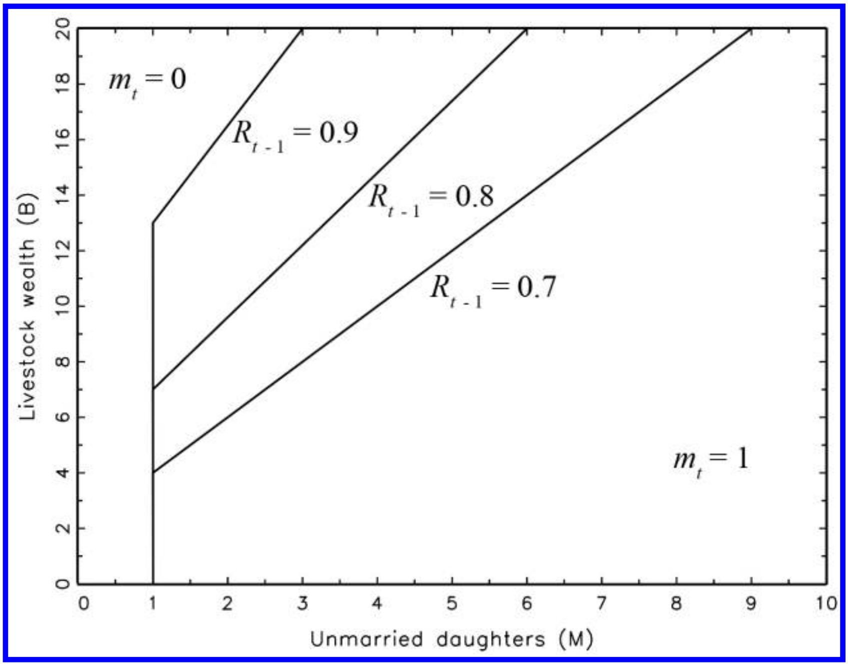

Figure 4. The marriage decision of households with M_t unmarried daughters and B_t livestock wealth. The area $m_t = 1$ describes combinations (M_t, B_t) for which it is optimal for the household to marry off a daughter. The amount of bride wealth is decreasing in the amount of rainfall.

B. Specification of the Statistical Model

Estimating the theoretical model structurally would be interesting, but we lack sufficient information in our data. In particular, our data contain only very limited information on bride wealth payments. The information on bride wealth suffers from item nonresponse and is only observed at the household level. It is thus not related to a particular marriage. In Section V.C we perform some empirical analyses with the data on bride wealth payments, but as we will also argue later the results should be interpreted with care because of the low data quality.

In the empirical model presented below, we focus on some predictions provided by the theoretical model that can be analyzed empirically. First, idiosyncratic shocks such as theft and death of cattle affect the marriage behavior of women. After a negative idiosyncratic shock households are likely to press their daughters to marry. Second, if the expected reduction in the amount of bride wealth over the age of marriage is substantial and increasing, then households prefer older daughters to marry first. And third, the effect of (correlated) rainfall shocks on marriage behavior is ambiguous.

Our empirical model focuses on unmarried women and the transition to being married. Our main interest is to investigate to what degree this marriage rate is affected by idiosyncratic shocks, rainfall shocks, and being the oldest unmarried daughter in the household. We do observe regional rainfall, but the data lack direct measures for idiosyncratic shocks, such as theft or death of cattle. It is not attractive to include the household's livestock wealth as a regressor representing idiosyncratic shocks. Households may differ in their preferences (e.g., instantaneous utility function or discount rate) or production function (e.g., land quality or available equipment), and, therefore, there can be households that are always poor and households that are always rich.[5] Girls from poorer households may prefer to marry younger, for instance, because living in a poor household is not very attractive. Therefore, we want the marriage rate to depend on idiosyncratic shocks to livestock wealth.

To construct idiosyncratic shocks we cannot simply take the difference in livestock wealth in a particular year compared to the average during the observation period. If a marriage occurs, bride wealth payments increase mean household livestock wealth, which implies that before the marriage the stock is low and after the marriage high. This might cause spurious relations between shocks and the marriage rate. Similar problems arise if we would define the shock as the difference in livestock wealth in subsequent years. Instead, we use a dynamic panel data model for livestock wealth accumulation to identify shocks in a household's livestock wealth (and the household's livestock wealth level).

Our data set contains information on H households that are denoted by $h = 1, \dots, H$. The panel is unbalanced, but the number of years T_h for which we observe household h is exogenous.[6] The theoretical model predicts that the household's livestock wealth $B_{h,t}$ (measured in cows) depends on (i) livestock wealth 1 year earlier $B_{h,t-1}$, (ii) a dummy variable $m_{h,t}$ that indicates whether a daughter in the household married between the survey in year $t - 1$ and year t, (iii) the size of the household $S_{h,t-1}$ during the survey in year $t - 1$, (iv) the amount of rainfall R_{t-1} in year $t - 1$, and (v) some household characteristics z_h that are constant over time. These include region, faith, and living in a single-headed household. We use the latter variable to further investigate the effect of household size and household composition.

The household's livestock wealth accumulates according to

[5] In our data the average livestock wealth is around 11.7 cows. The within-household standard deviation in livestock wealth is 3.3 cows, while the between-households standard deviation is 8.9 cows. This implies that there are, indeed, generally richer and poorer households, but being rich in a particular year does not guarantee being rich in the next year.

[6] We did not find any relation between the household's socioeconomic characteristics and participation in the survey.

$$B_{h,t} = \beta_0 + \beta_1 B_{h,t-1} + \beta_2 m_{h,t} + \beta_3 S_{h,t-1} + \beta_4 R_{t-1} + z_h \beta_5 + \eta_h + \varepsilon_{h,t},$$

where η_h is the household-specific wealth component and $\varepsilon_{h,t}$ is the idiosyncratic wealth shock. These are the two components that we want to include as regressors in the marriage rate. This specification for livestock wealth accumulation can be interpreted as the reduced form of equation (1) in the theoretical model. To estimate the model we use the generalized method of moments (GMM) framework of Arellano and Bond (1991), where we instrument (after taking first differences) the regressors $\Delta B_{h,t-1}$ and $\Delta m_{h,t}$ by $B_{h,t-2}$, $B_{h,t-3}$, $m_{h,t-1}$, $\Delta S_{h,t-2}$, and ΔR_{t-2}. We consider $\Delta S_{h,t-1}$ and ΔR_{t-1} as exogenous regressors in the first-difference specification.[7] The crucial assumption in this estimation procedure is that autocorrelation in $\varepsilon_{h,t}$ is ruled out. After having estimated the model we compute the residuals

$$\hat{u}_{h,t} = B_{h,t} - \hat{\beta}_1 B_{h,t-1} - \hat{\beta}_2 m_{h,t} - \hat{\beta}_3 S_{h,t-1} - \hat{\beta}_4 R_{t-1}.$$

These residuals are the sum of the household-specific wealth component, the idiosyncratic shocks, and the covariate effects of the time-invariant regressors. We can use these residuals to derive the density function $f(\eta_h, \varepsilon_{h,1}, \varepsilon_{h,2}, \ldots \varepsilon_{h,T_h} | \hat{u}_{h,1}, \hat{u}_{h,2}, \ldots \hat{u}_{h,T_h})$ (details are provided in app. B).

Our main interest is the marriage rate specified at the level of daughters instead of households. Woman $i = 1, \ldots, N$ lives in a household h_i with the household-specific wealth level η_{h_i} and yearly idiosyncratic wealth shock $\varepsilon_{h_i,t}$. Observed characteristics of the women are given by the vector $x_{i,t}$ (this vector also includes the [time-invariant] household characteristics and local rainfall). We allow the marriage rate to depend on unobserved individual characteristics θ_i and an unobserved household specific effect μ_{h_i}. The latter accounts for clustering of multiple unmarried women in one household. The marriage rate at age τ is assumed to have the familiar mixed proportional hazard (MPH) specification

$$\lambda(\tau | x_{i,t}, \eta_{h_i}, \varepsilon_{h_i,t}, \theta_i, \mu_{h_i}) = \psi(\tau) \exp(x_{i,t}\beta + \gamma\eta_{h_i} + \delta\varepsilon_{h_i,t} + \theta_i + \mu_{h_i}),$$

in which $\psi(\tau)$ is a piecewise constant baseline hazard, describing age dependence. Piecewise constant duration dependence implies that we estimate different parameters for age intervals. We take these age intervals to be 2 years.

To estimate the model we use a flow sample to avoid initial conditions problems. In the flow sample we follow women from the moment they reach the age at which they start getting married. Zimbabwe does not have a legal

[7] We have performed a Sargan test to test the specification of our model and the validity of the set of instrumental variables. The value of the test statistics equals 4.51. Since it follows a χ^2 distribution with three degrees of freedom, we cannot reject that the model is correctly specified and that the instrumental variables are valid.

minimum age for marriage, but the statistical bureau of Zimbabwe uses 15 as a lower bound. Of the women born between 1975 and 1980 fewer than 3% were reported to be married by the age of 15 (Central Statistical Office 1995). Our data do not show any marriages of women under age 15. Therefore, we use 15 as the minimum age to get married, which we denote by τ_0. So, when estimating the model, we only use a sample of women becoming 15 during the observation period. Note that we only model the age at first marriage.

Let τ be the actual age when getting married and t_0 the calendar time at birth. The conditional density function of $\tau | x_{i,t_0+\tau_0}, \ldots, x_{i,t_0+\tau}, \eta_{h_i}, \varepsilon_{h_i,t_0}, \ldots, \varepsilon_{h_i,t_0+\tau}, \theta_i, \mu_{h_i}$ can be written as

$$f(\tau | x_{t_0+\tau_0}, \ldots, x_{i,t_0+\tau}, \eta_{h_i}, \varepsilon_{h_i,t_0+\tau_0}, \ldots, \varepsilon_{h_i,t_0+\tau}, \theta_i, \mu_{h_i})$$

$$= \lambda(\tau | x_{i,t_0+\tau}, \eta_{h_i}, \varepsilon_{h_i,t_0+\tau}, \theta_i, \mu_{h_i})$$

$$\times \exp\left(-\int_{\tau_0}^{\tau} \lambda(s | x_{i,t_0+s}, \eta_{h_i}, \varepsilon_{h_i,t_0+s}, \theta_i, \mu_{h_i}) \mathrm{d}s\right), \ \tau \geq \tau_0.$$

Age and calendar time are genuinely continuous, but we only observe the year in which a woman gets married and the age of women at the time of the interview. To address this we have to integrate over yearly intervals in which women reached age 15 and got married. Let T be the stochastic variable denoting the date at which a woman gets married. Conditional on the year of inflow in the sample $t_0 + \tau_0$, that is, the year in which the woman became 15 and the vectors of explanatory variables $x_{i,t}$, $t = t_0 + \tau_0, t_0 + \tau_0 + 1, \ldots$, the probability of getting married between year t^* and $t^* + 1$ equals

$$\Pr(T \in [t^*, t^* + 1) | x_{i,t_0+\tau_0}, \ldots, x_{i,t^*}, \eta_{h_i}, \varepsilon_{h_i,t_0+\tau_0}, \ldots, \varepsilon_{h_i,t^*})$$

$$= \int_{t^*-t_0+\tau_0}^{t^*-t_0+\tau_0+1} \int_{\tau_0}^{\tau_0+1} \int_{(\theta,\mu)}$$

$$f(r + p | x_{i,t_0+\tau_0}, \ldots, x_{i,t^*}, \eta_{h_i}, \varepsilon_{h_i,t_0+\tau_0}, \ldots, \varepsilon_{h_i,t^*}, \theta, \mu) \mathrm{d}G(\theta, \mu) \mathrm{d}p \mathrm{d}r,$$

where $G(\theta, \mu)$ is a discrete distribution with unrestricted mass point locations.

The final complication is that we do not observe the values of η_i and $\varepsilon_{i,\tau}$. Instead we observe the estimated residuals $\hat{u}_{i,\tau}$. Therefore, we optimize the log likelihood function[8]

[8] Although it is not explicitly stated in the likelihood function, we impose the constraint that women living in the same household share the same unobserved household-specific component.

$$\log\left(\prod_{i=1}^{N}\int \Pr(T \in [\tau_i^*, \tau_i^* + 1) | x_{i,\tau_{0,i}+t_0}, \ldots, x_{i,\tau^*_i}, \eta_{h_i}, \varepsilon_{h_i,\tau_{0,i}+t_0}, \ldots, \varepsilon_{h_i,\tau^*_i}) \right.$$

$$\left. f(\eta_{h_i}, \varepsilon_{h_i,\tau_{0,i}+t_0}, \ldots, \varepsilon_{h_i,\tau^*_i} | \hat{u}_{h_i,1}, \hat{u}_{h_i,2}, \ldots) \mathrm{d}(\eta_{h_i}, \varepsilon_{h_i,\tau_{0,i}+t_0}, \ldots, \varepsilon_{h_i,\tau^*_i})\right).$$

We use simulated maximum likelihood estimation to optimize this log likelihood function (e.g., Stern 1997). In particular, we take 1,000 draws from the distribution $f(\eta_{h_i}, \varepsilon_{h_i,\tau_{0,i}+t_0}, \ldots, \varepsilon_{h_i,\tau^*_i} | \hat{u}_{h_i,1}, \hat{u}_{h_i,2}, \ldots)$. For each draw $j = 1, \ldots, 1{,}000$ we follow the procedure: (i) given the values $\hat{u}_{h_i,1}, \hat{u}_{h_i,2}, \ldots$ we generate a matrix $u^j_{h_i,1}, u^j_{h_i,2}, \ldots$, (ii) we generate a $\eta^j_{h_i}$ with household-specific effects from a normal distribution with mean 0 and variance $\hat{\sigma}^2_\eta$, (iii) we compute the shocks $\varepsilon^j_{h_i,\tau} = u^j_{h_i,\tau} - \eta^j_{h_i}$, (iv) we compute the individual likelihood contribution, and (v) we maximize the sum of the logarithm of the individual likelihood contributions.

The key identifying assumption in this model is that the error terms $\varepsilon_{h,t}$ describe true idiosyncratic wealth shocks. We, therefore, rule out that the error term contains measurement error, which would lead to an underestimation of the effect of idiosyncratic shocks on the marriage rate. Furthermore, we assume that there is no systematic autocorrelation in the error terms. In other words, we do not allow households to participate in alternative insurance schemes that smooth idiosyncratic shocks over time. The presence of such insurance schemes would cause an underestimation of the effect of idiosyncratic shocks on the marriage rates of daughters.

IV. Data

The data set we use is a yearly panel of Zimbabwean smallholder farmers covering the period 1994 until 2000. These households belong to the group of about 25,000 families that have been resettled in the early 1980s on land acquired from large-scale farmers after the independence. Approximately 400 households are interviewed, living in three different areas (Mpfurudzi, Sengezi, and Mutanda). Farmers located in Mpfurudzi live in a region most favorable to farming; those in Mutanda have to deal with the worst conditions.

Upon resettlement, each household was provided 12 acres of land for cultivation. The land presented to the households is about 10% of the resettlement scheme; the remaining 90% is common property land, which can be used for grazing. About 79% of the farmers in our data use less than 12 acres for agricultural production. For most households the availability of land is thus not the binding constraint in their agricultural production, especially as households can use more than 12 acres of land if they (illegally) reclaim some common property land or rent land from other farmers (indeed 12% of the farmers do so).

The resettlement farmers possess, on average, more land than regular smallholder farmers, and until 1992 heads of households were not allowed to work off farm. Regular farmers obtain approximately 30% of their income from nonfarm sources, whereas resettlement farmers earn only 5%–10% of their income off farm. Farmers in the resettlement scheme are also somewhat wealthier, and their per capita expenditures are about 10% higher than the per capita expenditures of ordinary smallholder farmers (Deininger, Hoogeveen, and Kinsey 2004).

Data collection was supervised by Bill Kinsey, and the data themselves are described in more detail in Kinsey et al. (1998). The surveys were fielded at the beginning of the calendar year and collected information on the previous year. Starting in 1994, information on all household members above age 14 was collected along with household characteristics. Prior to that, individual information was not collected. Household characteristics that have been collected include crop income and livestock possession. For individuals information was collected on age, level of education, gender, marital status, faith, and so forth. If an individual was not present at the time of the survey but was recorded as a household member in a previous survey, the reason why the individual left the household was asked. Women generally left the household because of marriage. So by comparing presence in the household and marital status in consecutive years, it became possible to construct spells of being unmarried.[9]

Since we are interested in the marriage behavior of young women, we restrict the data to unmarried women whose age exceeds 15 years at some interview. We only consider own daughters of the head of household. In total, we observe 691 unmarried women over age 15, of which in total 233 got married during the observation period. Figure 5 shows the Kaplan-Meier estimates of the survival probabilities, that is, the probability that a woman is still unmarried at a particular age. Most women married before age 30; only 4% were still unmarried at this age. At age 22, over 60% of the women got married. The median age of marrying in our data is around 21 years and thus higher than the median marriage age in Zimbabwe, which is 19 years. Note that our data describe a very specific rural setting with resettled farmers who are, on average, somewhat richer than other farmers.

[9] Sons are much more likely than daughters to leave the household unmarried to seek employment in town and get married while they are in town. This makes it more difficult to focus on the marriage behavior of sons. The labor market for girls consists of jobs like housekeeping.

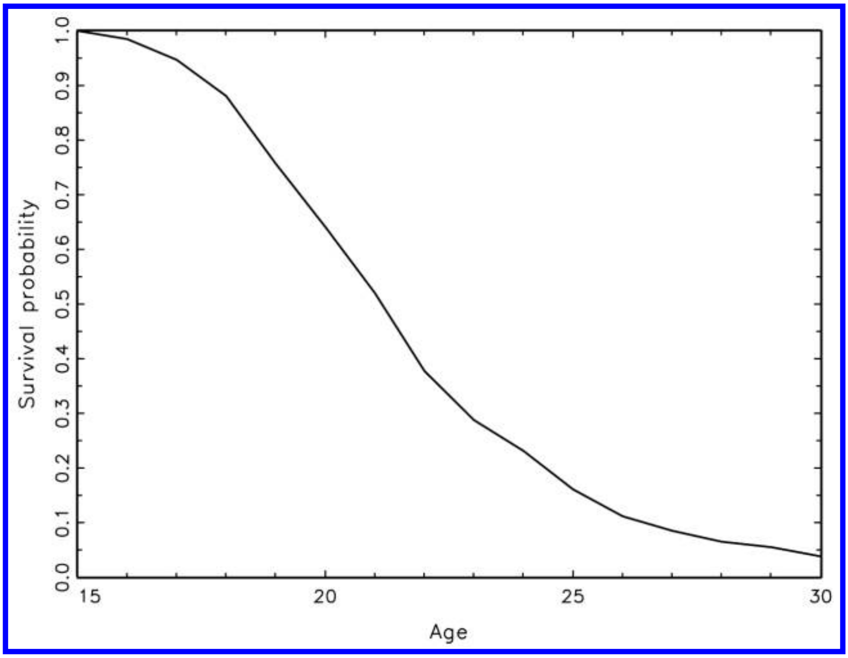

Figure 5. Kaplan-Meier estimate of the survivor function. This shows the percentage of women still unmarried at a given age.

In table 1 we present some annual statistics of the data, such as the number of marriages, the average marital age, and both local and average rainfall in Zimbabwe.[10] We stratified the sample by the region in which the women live. For each of the three regions, both the number of marriages and the average age of marriage decrease over the years. Also the sample size decreases over time. This is caused by the original sampling of the data, which includes households in which the man was between 35 and 50 years of age in 1982.[11] This implies that more women leave the sample (for reason of marriage), than young (unmarried) women enter the sample (because they reach age 15). Local rainfall is correlated with average rainfall in Zimbabwe, but there is variation between regions. In each of the regions rainfall was lowest in 1994/95, which affects the number of marriages in 1995. The data do not show strong differences in the number of marriages and the average age of marriage between years with large and low amounts of rainfall.

In Section III.B we mentioned the need to construct a flow sample of

[10] The local rainfall data and the Zimbabwean rainfall data are collected by the Department of Meteorological Services in Zimbabwe.

[11] A family remains in the data until both the man and woman die. After that the household is replaced by the people who move into their house (most likely sons or daughters).

TABLE 1
SOME ANNUAL STATISTICS OF THE SAMPLE OF UNMARRIED WOMEN IN THE AGE INTERVAL BETWEEN 15 AND 30

Year	Sample Size at Beginning of Year	Number of Marriages	Average Age of Marriage	Rainfall in Previous Season: Local	Rainfall in Previous Season: Zimbabwe
Mpfurudzi:					
1994	215	34	20.5	.69	.52
1995	209	29	19.9	.52	.42
1996	202	26	19.3	.77	.70
1997	182	25	19.4	1.25	.75
1998	180	17	18.4	.70	.53
1999	169	25	18.9	.99	.78
Mutanda:					
1994	84	9	21.1	.72	.52
1995	80	7	23.3	.58	.42
1996	86	10	18.4	.93	.70
1997	76	11	19.0	.97	.75
1998	63	3	18.3	.70	.53
1999	58	3	19.0	1.27	.78
Sengezi:					
1994	60	7	20.0	.52	.52
1995	60	9	18.1	.47	.42
1996	55	9	19.9	.90	.70
1997	51	5	20.8	.96	.75
1998	44	1	16.0	.72	.53
1999	39	3	17.7	.95	.78
Total		233			

Note. The quantity of rainfall is measured in meters per year and collected by the Department of Meteorological Services in Zimbabwe.

TABLE 2
SOME ANNUAL STATISTICS OF THE FLOW SAMPLE OF UNMARRIED WOMEN

Year	Sample Size at Beginning of Year	Number of Marriages	Average Age of Marriage
1994	62	0	. . .
1995	122	1	16.0
1996	175	8	16.3
1997	204	13	17.1
1998	219	12	17.3
1999	221	23	18.6
Total		57	

unmarried girls to avoid initial conditions problems. Therefore, we restrict the sample further to women who reached the marriageable age of 15 years during the observation period. This gives a sample of 333 women (originating from 220 different households), of which 57 got married during the observation period. Table 2 shows the number of women in this subsample at the beginning of a year and the number of marriages in that year. Most marriages occur in

TABLE 3
AVERAGE LIVESTOCK WEALTH (IN ITS REAL VALUE IN 1995) OWNED BY THE HOUSEHOLD, STRATIFIED BY THE WOMEN GETTING MARRIED IN A PARTICULAR YEAR OR NOT

	Livestock Wealth		
Year	Not Married	Married	*p*-Value for Difference
1994	9.7	. . .	. . .
1995	11.3	.5	.24
1996	12.0	6.6	.15
1997	12.7	10.7	.51
1998	13.6	9.1	.19
1999	13.4	14.7	.26

Note. In 1995, the prices (in Zimbabwean dollars) of cattle were: cow, 1,200; heifer, 1,000; trained ox, 1,800; young ox, 1,000; bull, 1,500; and goat, 85.

the last 3 years of the observation period. During the first 3 years, the women in the flow sample are all younger than 18. The marriage rate for this age group is low. Note that since we only have 6 years of data, the oldest women in the flow sample reach age 20 at the end of the observation period. This implies that we cannot say anything about marriage behavior beyond this age.

In table 3 we show average livestock wealth in each year for the subsample of women who got married in that year and those who remained unmarried. We observe that in each year except 1999, women who got married came from poorer households. The difference in wealth between the subsamples is particularly large in 1998, the year following the relative dry year 1997. This is consistent with our model's prediction that after a negative shock women in poor households are more likely to marry.

In figure 6 we show density functions of livestock wealth for different years. It can be seen that households are recovering from the drought of 1992, as over time fewer households have the livestock equivalent wealth of only a few cows. The exception is 1998, which follows on a year of relatively low rainfall. A household needs two head of cattle to avoid having to prepare the land with the hoe. In table 4 we show that around 57% of the households have a livestock equivalent less than 10 cows, and about 11% of the households have a livestock equivalent of less than two cows. Hence a substantial share of households does not have any buffer stock or enough draft power for plowing.

On average, women in our sample live in a household comprising about 12 persons (including the parents). A variable we include as regressor is an indicator for being the oldest unmarried daughter in the household. Furthermore, we use region and faith as explanatory variables. Most women in the sample live in villages in Mpfurudzi. In terms of religious denomination, around 17% of the women report that they adhere to traditional African faith

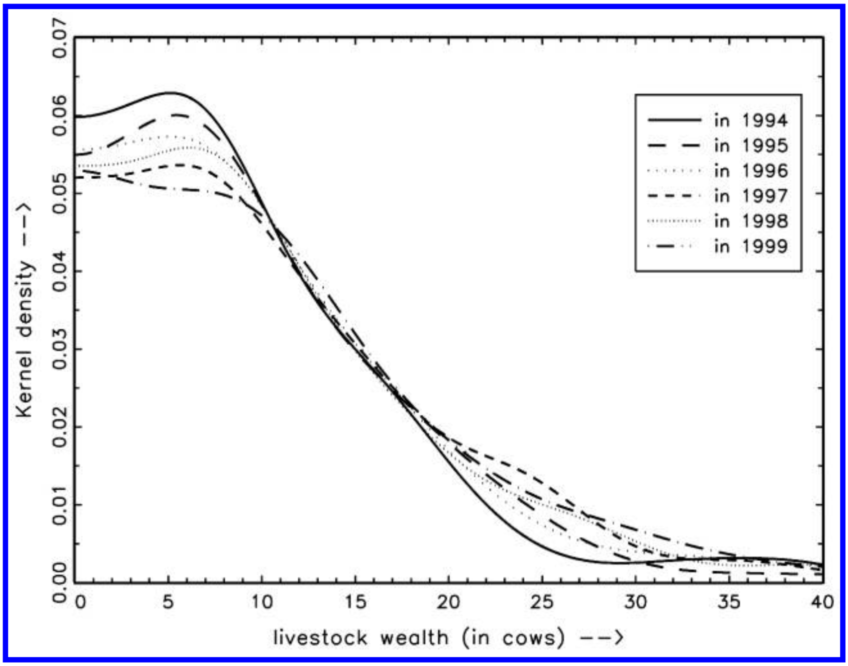

Figure 6. Kernel estimate for the livestock wealth density function for different years

TABLE 4
SOME CHARACTERISTICS OF THE HOUSEHOLD LIVESTOCK WEALTH DISTRIBUTION

Year	≤ Two Cows (%)	≤ 10 Cows (%)	Previous Rainfall
1994	15.7	63.5	.52
1995	11.2	59.0	.42
1996	9.0	57.9	.70
1997	11.0	54.8	.75
1998	12.6	57.0	.53
1999	11.5	51.1	.78

and 7% to the Johane Masowe Apostolic Faith Sect. The remaining women mostly have Christian faith, which is generally less strict than the African and Masowe faith. In 17% of the cases the father is missing in the household, and in 4% the mother. For around 11% of the women all household characteristics are missing for all years. Since our sample is relatively small we include a dummy variable for these women.

The data contain some information on the amount of bride wealth paid (and especially on the amount of *danga*, i.e., the most substantial payment). This variable needs to be interpreted with care. The information on bride wealth is affected by item nonresponse, and bride wealth payments are only observed at the household level, as the total amount of bride wealth obtained in the previous year. It is thus not related to a particular marriage. By combining the individual data on marriages with the household data on bride wealth payments, we try to relate bride wealth to marriages. In particular, if we observe the household receiving bride wealth we link this to the most recent marriage that occurred in this household. For the year 2000 we did not obtain any information on bride wealth.

We create two variables concerning bride wealth. The first contains the amount of bride wealth received by the household in the year of marriage, which we refer to as short-term bride wealth. The second, called long-term bride wealth, is the accumulated amount of bride wealth received by the household in the year of marriage and the following years in the observation period. However, recall that it usually takes around 30 years until the total amount of bride wealth has been paid, while we only observe yearly payments over a maximum of 5 years. Only for 128 households in which a marriage occurred we observed information on bride wealth payments. The average bride wealth in the year of the marriage consisted of around 1,300 Zimbabwean dollars (either in cash or in cattle). In 1992, the exchange rate was 7.2 Zimbabwean dollars for one U.S. dollar.

With respect to long-term bride wealth, we only include marriages until 1997; otherwise the total observed bride wealth would be too much affected by the remaining length of the observation period after the year of marriage. This subsample includes 174 marriages. For 156 of these 174 we observe bride wealth. The average bride wealth was approximately 2,200 Zimbabwean dollars.

V. Estimation results

A. Parameter estimates

In this section we present the results of the empirical analyses. The parameter estimates are presented in table 5. We do not find any significant unobserved heterogeneity, neither at the individual level nor at the household level. The baseline hazard shows how the marriage rate is affected by the age of an unmarried woman; the marriage rate significantly increases with age.

We distinguish two types of shocks, (correlated) rainfall shocks and idiosyncratic shocks in livestock wealth. The main parameters of interest are associated with shocks. Our theoretical model showed that the effect of rainfall on marriage could either be positive or negative, depending on the sensitivity of the amount of bride wealth to rainfall. An idiosyncratic wealth shock does not have equilibrium effects, and exposure to such a shock should thus increase the marriage rate.

The estimated effect of rainfall on the marriage rate is positive but not

TABLE 5
ESTIMATION RESULTS FOR THE MARRIAGE RATE

	Marriage Hazard	
	Coefficient	SE
Intercept:		
v	−5.38**	.99
Baseline hazard (age):		
λ_{15-16}	0	
λ_{17-18}	1.04**	.40
λ_{19-20}	2.02**	.52
Region:		
Mpfurudzi	0	
Mutanda	−.26	.39
Sengezi	−.50	.45
Faith:		
Christian	0	
African	−.78	.67
Masowe faith	−.40	.61
Rainfall (in meters)	.64	.77
Individual and household characteristics:		
Oldest unmarried daughter	.51	.35
Missing	1.97**	.56
Household size	.083**	.027
Parent absent	.41	.39
Livestock wealth shock ($\varepsilon_{i,t}$ in cows)	−.10**	.049
Livestock wealth level (η_i in cows)	−.025	.026
$\log \mathcal{L}$	−185.76	
N	333	

** Significant at the 5% level.

statistically significant. Recall that in our flow sample most marriages took place between 1996 and 1999. It might be that the amount of local rainfall in these years does not yield sufficient variation to precisely estimate the effect on the marriage rate. Indeed, the insignificance of the effect is caused rather by a large standard error than a small coefficient. If we take the estimated coefficient seriously we could conclude that in 1999 the marriage rate was on average around 38% higher than in 1995.[12] Recall that quantity of rainfall varied from around 0.5 meter in 1994 to around 1 meter in 1996 and 1998. The effect of the amount of rainfall is thus merely a marriage market effect. Like brides (and their families) grooms suffer from the negative weather shocks. After a drought they are likely to be reluctant to get married and to pay bride wealth.

The idiosyncratic shocks in livestock wealth $\varepsilon_{b_i,t}$ have a negative effect on the marriage rate. The estimated coefficient is not only statistically significant but also quite substantial. If a household loses two head of cattle, due to an

[12] This effect can be computed from the estimation results as $\exp(0.64 \cdot 0.5) - 1 \approx 0.38$.

unanticipated event such as theft, the marriage rate of daughters in this household increases around 22%. This is in agreement with the theoretical model. The effect of idiosyncratic shocks on livestock wealth $\varepsilon_{h_i,t}$ is more important than differences between household-specific components η_{h_i}. The covariate effect of the household-specific wealth component η_{h_i} is also negative but not significant.

Our third parameter of interest is the effect of being the oldest unmarried daughter in the household. Our theoretical model predicted that if the amount of bride wealth is decreasing faster in age for older girls, then households prefer the oldest daughter to marry first.[13] Indeed, the marriage rate of the oldest daughter is 67% higher than the marriage of a girl of the same age, who has an older unmarried sister. However, this effect is not significant; the p-value is about .14. Since the model takes account of the age of women, this is not a spurious effect due to the fact that the average age of oldest daughters is most likely to be higher than of the other unmarried women.

Finally, as predicted by our theoretical model, the size of the household has a significant positive effect on the marriage rate, implying that daughters living in larger households marry on average younger. In larger households the loss of labor due to a marriage is less severe. Recall that because the land of a household is fixed, the marginal productivity of a daughter in larger households is smaller than in smaller households. Alternatively, large households are likely to have many sons, which are (due to bride wealth) claims on household wealth. Ideally, the marriage of a daughter precedes the marriage of a son, and thus women living in households with many brothers have more pressure to marry. Therefore, we have tried to replace household size with the number of sons in the household. This did not affect the parameter estimates. Both variables are too much correlated to be included jointly. The effect of living in a single-headed household is positive (not significant), which suggests that women in single-headed households marry earlier. Note that we do not observe the reason why a parent is absent.

B. Robustness Checks

In this subsection we provide sensitivity analyses with respect to our model specification. Since our data do not directly measure shocks in livestock wealth, we had to construct them from the residuals from the dynamic wealth accumulation function. In the sensitivity analyses we focus on these shocks.

[13] An alternative reason why households would put most pressure on the oldest daughter to get married is that other daughters could easily argue against their parents' pressure to marry on the ground that they have an older unmarried sister.

TABLE 6
ESTIMATION RESULTS FOR THE MARRIAGE RATE INCLUDING OBSERVED LIVESTOCK WEALTH AS REGRESSOR

	Marriage Hazard	
	Coefficient	SE
Intercept:		
v	−5.00**	.94
Baseline hazard (age):		
$\lambda_{15–16}$	0	
$\lambda_{17–18}$	1.05**	.39
$\lambda_{19–20}$	2.11**	.47
Region:		
Mpfurudzi	0	
Mutanda	−.31	.38
Sengezi	−.46	.43
Faith:		
Chistian	0	
African faith	−.61	.63
Masowe faith	−.35	.58
Rainfall (in meters)	.77	.77
Individual and household characteristics:		
Oldest daughter	.45	.33
Missing	1.48**	.56
Household size	.080**	.025
Parent absent	.38	.38
Livestock wealth (in cows)	−.028	.019
$\log \mathcal{L}$	−186.90	
N	333	

** Significant at the 5% level.

In our first sensitivity analysis, we replace both the idiosyncratic wealth shocks and the household-specific wealth component by the observed livestock wealth of the household. The parameter estimates are presented in table 6. The estimated coefficient of livestock wealth is negative and has about the same value as the coefficient for the household specific wealth component in the baseline model. The estimated effect of livestock wealth is also insignificant. We can, therefore, conclude that the livestock wealth mainly describes differences between households rather than shocks occurring to the household. Recall that the variation in livestock wealth between households is larger than the variation in livestock wealth within a household.

A more appropriate measure for shocks might be the difference in the household's livestock wealth in two subsequent years. In the second robustness check, we include this measure for shocks. The parameter estimates presented in table 7 show that a reduction in livestock wealth increases the marriage rate of daughters in the household, but the effect is insignificant. It should, however, be noted that these shocks are bigger in wealthier households because the shocks also contain natural depreciation (or growth rate) of livestock. Since

TABLE 7
ESTIMATION RESULTS FOR THE MARRIAGE RATE INCLUDING THE DIFFERENCE IN OBSERVED LIVESTOCK WEALTH AS REGRESSOR

	Marriage Hazard	
	Coefficient	SE
Intercept:		
v	−5.26**	.96
Baseline hazard (age):		
λ_{15-16}	0	
λ_{17-18}	1.00**	.39
λ_{19-20}	2.01**	.47
Region:		
Mpfurudzi	0	
Mutanda	−.25	.37
Sengezi	−.45	.43
Faith:		
Christian	0	
African faith	−.66	.63
Masowe faith	−.46	.58
Rainfall (in meters)	.75	.77
Individual and household characteristics:		
Oldest daughter	.49	.34
Missing	1.77**	.53
Household size	.076**	.026
Parent absent	.38	.38
Difference in livestock wealth (in cows)	−.028	.020
$\log \mathcal{L}$	−187.65	
N	333	

** Significant at the 5% level.

we expect marriage rates to be lower in wealthier families, this might cause an underestimation of true effects of shocks in livestock wealth.

We mentioned earlier that households need two head of cattle for plowing. If a household owns less cattle, the household may be stuck in poverty for a long time. Marriage of a daughter can then be a way out of such a poverty trap. Therefore, we replace the variables describing the livestock wealth of a household by a dummy variable indicating whether the household possesses less than two cows. The parameter estimates presented in table 8 show that marriage rates are significantly higher in households with livestock wealth less than two cows. The effect is quite substantial; marriage rates in such poor households are 170% higher than in other households. This result confirms the predictions of our theoretical model, that is, households might use the marriage of a daughter to escape from a possible poverty trap.[14]

Finally, recall from Section IV that for some households we do not observe

[14] Shocks may have different effects on poor and relatively wealthy household. Therefore, we have tried to interact the idiosyncratic shocks with the indicator for owning less than two cows. However, this specification asks too much from the data, and standard errors explode.

TABLE 8
ESTIMATION RESULTS FOR THE MARRIAGE RATE INCLUDING LIVESTOCK WEALTH LESS THAN TWO COWS AS REGRESSOR

	Marriage Hazard	
	Coefficient	SE
Intercept:		
v	−5.37	.95
Baseline hazard (age):		
λ_{15-16}	0	
λ_{17-18}	1.04**	.39
λ_{19-20}	2.12**	.47
Region:		
Mpfurudzi	0	
Mutanda	−.38	.39
Sengezi	−.49	.43
Faith:		
Christian	0	
African faith	−.68	.62
Masowe faith	−.43	.58
Rainfall (in meters)	.76	.77
Individual and household characteristics:		
Oldest daughter	.47	.33
Missing	1.88**	.53
Household size	.080**	.026
Parent absent	.24	.39
Livestock wealth less than two cows	1.00**	.51
$\log \mathcal{L}$	−186.55	
N	333	

** Significant at the 5% level.

any household characteristics. In the main specification we have included a dummy variable for these households. This implicitly assumes that these households are homogenous, while there might be substantial differences, for example, in livestock wealth. Therefore, we have estimated our model again using only those households for which we observe all household characteristics. This excludes 38 of the 333 observations in our subsample. As can be seen from table 9, the parameter estimates do not change much. Only the standard errors increase slightly.

C. Analyzing the Amount of Bride Wealth Payments

The empirical analyses above show that after an idiosyncratic shock, households are more likely to marry off a daughter to obtain new livestock. An alternative explanation might be that after a shock there is insufficient food for all household members. In this subsection we analyze data on the amount of bride wealth payments to get some insight into the underlying mechanism. If the main reason for marrying a daughter is that households need new livestock, their main interest is to get high payments at the time of marriage. However,

TABLE 9
ESTIMATION RESULTS OF THE MODEL USING ONLY THE SUBSAMPLE FOR WHICH ALL HOUSEHOLD CHARACTERISTICS ARE OBSERVED

	Marriage Hazard	
	Coefficient	SE
Intercept:		
v	−5.52	1.13
Baseline hazard (age):		
λ_{15-16}	0	
λ_{17-18}	.92**	.45
λ_{19-20}	1.97**	.56
Region:		
Mpfurudzi	0	
Mutanda	−.023	.43
Sengezi	−.12	.52
Faith:		
Christian	0	
African faith	−.99	.76
Masowe faith	−.40	.64
Rainfall (in meters)	.66	.94
Individual and household characteristics:		
Oldest daughter	.46	.40
Household size	.093**	.028
Parent absent	.45	.41
Livestock wealth shock ($\varepsilon_{i,t}$ in cows)	−.10**	.049
Livestock wealth level (η_i in cows)	−.024	.026
$\log \mathcal{L}$	−159.21	
N	295	

** Significant at the 5% level.

this would not be the case if households only want to reduce the number of people they have to feed. In that case, households would not substitute long-term bride wealth payments for short-term payments.

As mentioned in Section IV, the data on the amount of the bride wealth are not very precise and do not cover a sufficiently long period. Therefore, the estimation results should be interpreted with care. For the empirical analyses we use tobit models.[15] We perform two analyses, the first based on the amount

[15] Since we only observe the amount of bride wealth for a subsample of the data, the ideal model would be a sample selection model. However, identification of sample selection models hinges on exclusion restrictions. In our data there is no variable that would qualify for being excluded from the equation denoting the amount of bride wealth but included in the equation describing if the household reports having received bride wealth. Therefore, we use a simpler censored regression or tobit model,

$$y^* = x\beta + \varepsilon$$

and

$$y = \begin{cases} y^* & \text{if } y^* > 0 \\ 0 & \text{if } y^* \leq 0 \end{cases}.$$

The interpretation of this model is that bride wealth is observed with a (large) measurement error

TABLE 10

ESTIMATION RESULTS OF THE CENSORED REGRESSION (TOBIT) MODEL FOR THE AMOUNT OF BRIDE WEALTH (IN COWS) RECEIVED IN THE YEAR OF MARRIAGE (SHORT TERM) AND RECEIVED IN TOTAL (LONG TERM)

	Bride Wealth Payments			
	Short Term		Long Term	
	Coefficient	SE	Coefficient	SE
Intercept	1.02	3.10	1.73	1.35
Age	−1.14	.090	.024	.051
Rainfall	−1.85	3.11	−1.21	1.51
Oldest daughter	.72	.62	−.14	.41
Livestock wealth (in cows)	−.043	.035	.027	.019
σ	.93	.037	2.08	.097
N	424		174	

of bride wealth received during the year of marriage and the second based on the accumulated amount of bride wealth received during the observation period after the marriage. The latter also includes the bride wealth received in the year of marriage. As explanatory variables we include age of the daughter at the moment of marriage, amount of rainfall, an indicator for being the oldest daughter, and livestock wealth in the year before marriage.

The estimation results are given in table 10. Except for rainfall all covariate effects on the amount of bride wealth received in the year of marriage are opposite to the effect on the total amount of the bride wealth. Obviously, some (impatient) households prefer a relatively large amount of bride wealth at the moment of marriage over a larger overall amount of bride wealth. The amount of bride wealth received at the first year is higher in relatively dry years, for poorer households, and if it is the oldest daughter who marries. The dummy variable for oldest daughter can be interpreted as an indicator for household pressure. It is clear that households that bargain for a relatively large initial payment of bride wealth have to accept lower payments in the following years. This observation is in accordance with our theoretical model; poor households need sufficient cattle for agricultural production. Therefore, they need a substantial initial transfer, which is obviously followed by a period with low transfers.

VI. Conclusions

This paper focuses on the timing of marriage in rural areas in Zimbabwe and provides evidence suggesting that the timing of marriage responds to economic circumstances. As the transfer of bride wealth from (the family of) the groom to the family of the bride upon a daughter's marriage presents an opportunity

ε and that households only report having received bride wealth if the bride wealth including the measurement error exceeds 0.

to acquire cattle, an unmarried daughter might be considered part of a household's asset portfolio. In this view an unmarried daughter could be considered an asset that can be cashed in during times of adversity. The central question we address is whether marriage (through bride wealth payments) serves as an alternative financial insurance institution.

The estimation results show that the amount of rainfall has a positive but insignificant effect on the marriage rate. This is likely a marriage market effect due to the fact that after a period of low rainfall the supply of men is lower as few households are able to afford bride wealth. The results also indicate that the marriage rate for daughters from poor households is higher. In particular, after a negative shock to livestock wealth the marriage rate of daughters increases. The marriage rate for the oldest daughter in the household is also found to be higher, but its coefficient is not significant. These empirical results are consistent with the hypothesis that households use unmarried daughters as assets that can be cashed in during times of adversity.

Of course, there are many other implicit insurance mechanisms that households use to deal with adverse shocks. However, from the empirical results that households use unmarried daughters to deal with adverse idiosyncratic shocks, one concludes that these other insurance mechanisms are insufficient to deal with all these shocks.

We considered the amount of bride wealth as well. Our estimation results provide additional evidence that the timing of marriage is used to avoid getting stuck in poverty. In particular, less wealthy households receive larger initial bride wealth payments when a daughter gets married. The accumulated amount of bride wealth they receive in the first years of marriage is relatively low so that the relatively high initial payment goes at the expense of subsequent payments. In other words, initial poverty can be avoided but only at the expense of lower payments in the subsequent years.

Appendix A

Parameterization of the Theoretical Model

For the simulation of our theoretical model, we used the following model specification. The planning horizon T of a household equals 14 years, which can be interpreted as the period that a household with unmarried daughters exists. The production function of the household $q_t = f(B_t, M_t, R_t)$ follows a Cobb-Douglas specification:

$$q_t = I(B_t \geq 2)0.5B_t^{0.5}(M_t + 4)^{0.5}R_t^2.$$

Because M_t denotes the number of daughters, we set total labor input equal to $M_t + 4$, taking parents and other family members (sons) into account. Rainfall R_t is uniformly distributed on the interval [0.6, 1].

We take the instant utility function to be of the CRRA type and the household's discount rate is 0.2, so lifetime utility equals

$$U_t = \sum_{\tau=t}^{14} (1 + 0.2)^{t-\tau} \frac{1}{1\text{–}0.5} c_t^{1-0.5}.$$

The depreciation rate of cattle is set to 0.95. We have used two specification for the amount of bride wealth. In the first specification the amount of bride wealth does not vary over time and equals three head of cattle. In the second specification the amount of bride wealth depends on the rainfall in the previous year, in particular $p_t = 2 + 5(R_{t-1} - 0.6)$. Finally, the idiosyncratic shocks are normally distributed with mean zero and standard deviation 0.5.

At each point in time t, for each $M_t = 0, 1, \ldots$ we used a fourth order polynomial in B_t to approximate $U_t(B_t, M_t)$. For the model specification where the amount of bride wealth depends on rainfall in the previous period, R_{t-1} is also a state variable. We used for each t and each $M_t = 0, 1, \ldots$ a polynomial of order four in B_t, of order three in R_{t-1}, and one interaction term between B_t and R_t to approximate $U_t(B_t, M_t, R_{t-1})$.

We have performed sensitivity analyses with respect to the parameterization. Increasing the variance of the idiosyncratic (wealth) shocks shifts the border between the $m_t = 0$ and the $m_t = 1$ areas to the left; increased uncertainty leads to more marriages at a given livestock wealth.

Appendix B
Estimating the Marriage Rate Including Idiosyncratic Wealth Shocks as Regressors

In this appendix, we provide the details of estimating the marriage rate. The household's livestock wealth accumulates according to

$$B_{h,t} = \beta_0 + \beta_1 B_{h,t-1} + \beta_2 m_{h,t} + \beta_3 S_{h,t-1} + \beta_4 R_{t-1} + z_h \beta_5 + \eta_h + \varepsilon_{h,t}.$$

To estimate the model we use the GMM framework of Arellano and Bond (1991), where we instrument (after taking first differences) the regressors $\Delta B_{h,t-1}$ and $\Delta m_{h,t}$ by $B_{h,t-2}$, $B_{h,t-3}$, $m_{h,t-1}$, $\Delta S_{h,t-1}$, $\Delta S_{h,t-2}$, ΔR_{t-1}, and ΔR_{t-2}.

Next, we impose the constraint that both η_h and $\varepsilon_{h,t}$ follow a normal distribution with mean zero and variance σ_η^2 and σ_ε^2, respectively. As an estimator for σ_ε^2, we use

$$\hat{\sigma}_\varepsilon^2 = \frac{1}{H}\sum_{h=1}^{H} \frac{1}{T_h - 1} \sum_{t=1}^{T_h} \left(\hat{u}_{h,t} - \frac{1}{T_h} \sum_{t=1}^{T_h} \hat{u}_{h,t} \right)^2,$$

where

TABLE B1
ESTIMATION RESULTS FOR THE HOUSEHOLD'S LIVESTOCK WEALTH ACCUMULATION MODEL

		Livestock Wealth	
	Parameters	Coefficients	SE
Lagged livestock wealth	β_1	.053	.086
Marriage	β_2	.81	.64
Household size	β_3	−.0061	.098
Rainfall	β_4	.73	.64
	σ_ε^2	21.4	
Intercept	β_0	10.53	2.78
Mutunda	β_5	−2.09	1.31
Sengezi	β_5	.61	1.35
Parent absent	β_5	−1.67	1.25
African faith	β_5	2.05	1.46
Masowe faith	β_5	−.058	2.19
	σ_η^2	69.8	
H		290	
$\sum_{h=1}^{H}(T_h - 1)$		1,006	

$$\hat{u}_{h,t} = B_{h,t} - \hat{\beta}_1 B_{h,t-1} - \hat{\beta}_2 m_{h,t} - \hat{\beta}_3 S_{h,t-1} - \hat{\beta}_4 R_{t-1}.$$

When computing the standard errors for $\hat{\beta}_1$, $\hat{\beta}_2$, $\hat{\beta}_3$, and $\hat{\beta}_4$, we have corrected for correlation between $\Delta\varepsilon_{h,t}$ and $\Delta\varepsilon_{h,t-1}$, that is, $\mathrm{Cov}(\Delta\varepsilon_{h,t-1}, \Delta\varepsilon_{h,t}) = -\sigma_\varepsilon^2$ and $\mathrm{Var}(\Delta\varepsilon_{h,t}) = 2\sigma_\varepsilon^2$. The estimation results are given in upper panel of table B1.

Next, we estimate the parameters β_0 and β_5. Therefore, we use the regression

$$\frac{1}{T_h}\sum_{t=1}^{T_h} \hat{u}_{h,t} = \beta_0 + z_h \beta_5 + e_h,$$

where it can be shown that

$$e_h = \eta_h + \frac{1}{T_h}\sum_{t=1}^{T_h} \varepsilon_{h,t} + \frac{1}{T_h}\sum_{t=1}^{T_h} (\beta_1 - \hat{\beta}_1)B_{h,t-1} + (\beta_2 - \hat{\beta}_2)m_{h,t}$$
$$+ (\beta_3 - \hat{\beta}_3)S_{h,t-1} + (\beta_4 - \hat{\beta}_4)R_{t-1}.$$

We can use ordinary least squares (OLS) to estimate the parameters β_0 and β_5, but when computing standard errors we have taken into account that the disturbances e_h are all correlated with each other and that they suffer from heteroskedasticity. The estimation results are reported in the lower panel of table B1.

Below we need the complete variance-covariance matrix of $[\hat{\beta}_0; \hat{\beta}_5']'$ and $[\hat{\beta}_1; \hat{\beta}_2; \hat{\beta}_3; \hat{\beta}_4]'$. Therefore, we use

$$\begin{bmatrix} \hat{\beta}_0 & -\beta_0 \\ \hat{\beta}_5 & -\beta_5 \end{bmatrix} = ([\iota; Z]' \, [\iota; Z])^{-1} \, [\iota; Z]' \begin{bmatrix} e_1 \\ \vdots \\ e_H \end{bmatrix},$$

where ι is a vector containing 1s and Z is a matrix with the vectors z_h. As we know how e_h depends on $\hat{\beta}_1$, $\hat{\beta}_2$, $\hat{\beta}_3$, and $\hat{\beta}_4$, we get an expression for the covariance matrix between $[\hat{\beta}_0; \hat{\beta}_5']'$ and $[\hat{\beta}_1; \hat{\beta}_2; \hat{\beta}_3; \hat{\beta}_4]'$, which we denote by the vector $\hat{\Omega}$.

We are interested in η_h and $\varepsilon_{h,t}$, but can estimate the residuals

$$\hat{v}_{h,t} = w_{h,t} - \hat{\beta}_0 - \hat{\beta}_1 w_{h,t-1} - \hat{\beta}_2 m_{h,t} - \hat{\beta}_3 x_{h,t-1} - \hat{\beta}_4 r_{t-1} - z_h\hat{\beta}_5.$$

Let η be a vector containing all household-specific effects, ε a matrix containing for all households all yearly shocks, and $\hat{v}$ the matrix containing the estimated residuals $\hat{v}_{h,t}$.

The remaining problem is to specify the density function $f(\eta, \varepsilon|\hat{v})$. We rewrite this density function by conditioning on a matrix v containing the elements $v_{h,t} = \eta_h + \varepsilon_{h,t}$, as

$$f(\eta, \varepsilon|\hat{v}) = \int f(\eta, \varepsilon|v, \hat{v}) f(v|\hat{v}) dv.$$

It is clear that if we know v, then $\hat{v}$ is not informative about η and ε, thus

$$f(\eta, \varepsilon|v, \hat{v}) = f(\eta, \varepsilon|v).$$

This density function can be written as

$$\begin{aligned}
f(\eta, \varepsilon|v) &= \prod_{h=1}^{H} f(\eta_h, \varepsilon_{h,1} \ldots, \varepsilon_{h,T_h}|v_{h,1}, \ldots, v_{h,T_h}) \\
&\propto \prod_{h=1}^{H} f(v_{h,1}, \ldots, v_{h,T_h}|\eta_h, \varepsilon_{h,1}, \ldots, \varepsilon_{h,T_h}) f(\eta_h, \varepsilon_{h,1}, \ldots, \varepsilon_{h,T_h}) \\
&= \prod_{h=1}^{H} \phi(\eta_h) \prod_{t=1}^{T_h} I(\varepsilon_{h,t} = v_{h,t} - \eta_h)\phi(\varepsilon_{h,t}).
\end{aligned}$$

Only in the last step we used that both η_i and $\varepsilon_{i,t}$ follow normal distributions.

Next, we have to focus on $f(v|\hat{v})$. Note that

$$\begin{aligned}
v_{h,t} &= B_{h,t} - \beta_0 - \beta_1 B_{h,t-1} - \beta_2 m_{h,t} - \beta_3 S_{h,t-1} - \beta_4 R_{t-1} - z_h\beta_5 \\
&= \hat{\beta}_0 + \hat{\beta}_1 B_{h,t-1} + \hat{\beta}_2 m_{h,t} + \hat{\beta}_3 S_{h,t-1} + \hat{\beta}_4 R_{t-1} + z_h\hat{\beta}_5 + \hat{v}_{h,t} \\
&\quad - \beta_0 - \beta_1 B_{h,t-1} - \beta_2 m_{h,t} - \beta_3 S_{h,t-1} - \beta_4 R_{t-1} - z_h\beta_5 \\
&= (\hat{\beta}_0 - \beta_0) + (\hat{\beta}_1 - \beta_1)B_{h,t-1} + (\hat{\beta}_2 - \beta_2)m_{h,t} \\
&\quad + (\hat{\beta}_3 - \beta_3)S_{h,t-1} + R_{t-1}(\hat{\beta}_4 - \beta_4) + z_h(\hat{\beta}_5 - \beta_5) + \hat{v}_{h,t}.
\end{aligned}$$

This implies that the matrix v is asymptotically normal distributed with mean

$\hat{v}$ and variance-covariance matrix $X\hat{\Omega}X'$, where X is a matrix that contains rows $[1; B_{h,t-1}; m_{h,t}; S_{h,t-1}; R_{t-1}; z_h]$.

In the simulated maximum likelihood procedure we draw 1,000 times from the distribution $f(\eta, \varepsilon | \hat{v})$. Therefore, we follow the procedure: (i) given the values $\hat{v}$ we generate a matrix v_j, (ii) we generate a vector η_j with household-specific effects from a normal distribution with mean 0 and variance $\hat{\sigma}^2_\eta$, (iii) we compute the matrix of shocks $\varepsilon_j = v_j - \eta_j$, and (iv) we compute the likelihood contribution and we weight this by $p_j = \phi(\varepsilon_j)$.

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