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Menarche, Marriage Age, Education, and Employment in Africa, the Middle East, and Central Asia

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Abstract: Child marriage is still relatively common in low-income countries, with 40% of Sub-Saharan African and 25% of Middle Eastern girls marrying before the age of 18. Case studies in individual countries have shown that delaying marriage for girls is associated with more years of schooling and a higher probability of employment. Many of these studies have used menarche, the age of a girl's first menstrual period, as an instrument for marriage age to avoid omitted variable bias. This paper tests and demonstrates the external validity of these case studies across 12 countries using data from demographic health surveys. We show that age at menarche is a potential instrument for marriage age in the pooled sample and stronger in countries with higher rates of child marriage. The results support previous findings that delayed marriage is associated with a higher number of years of school completed and probability of employment, with a few exceptions where average marriage age is higher. This work adds to the evidence base for policy to increase marriage age for the long-term well-being of women in low-income countries.

Keywords: Child Marriage, Women's Employment, Menarche
JEL Codes: O12, I25

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Section 1: Introduction

Child marriage in low-income countries harms young women's employment and education opportunities (Parsons et al., 2015; Jamel & Joshi, 2020; Ahonsi et al., 2019; de Groot et al., 2018). Worldwide, 140 million girls will marry before the age of 18, roughly 40,000 girls every day (Parsons et al., 2015). The rate at which girls are being married before the age of 18 has declined in Sub-Saharan Africa, but the region still has the highest rates of child marriage in the world (Koski, Clark, & Nandi, 2017). In sub-Saharan Africa, 40 percent of girls marry before age 18 (Smaak & Varia, 2015). Child marriage rates are also high in the neighboring Middle East. In the past 25 years, the Middle East has seen a decline in child marriage rates, from one in every three marriages to one in every five (Karasapan & Shah, 2019).

Child marriage is often driven by poverty, when households have fewer resources and opportunities to invest in girls (Parsons et al., 2015; Tsaneva, 2020). From a causal analysis standpoint, this presents a challenge since unobservable variables such as parents' wealth or desire for daughters' education may create bias when measuring the relationship between child marriage and education outcomes. To address unobservable factors, many studies have used the age of menarche, the first occurrence of menstruation, as an instrumental variable (Sunder, 2019; Field & Ambrus, 2008; Raj et al., 2015; Asadullah & Wahhaj, 2019). Field and Ambrus (2008) suggested in their study of Bangladesh that families withhold girls from marriage until they reach puberty as measured by menarche. Field and Ambrus hypothesize that the quasi-random nature of menarche age makes it a potential instrument for marriage age. These case studies have established the relationship between menarche and early marriage in the context of individual countries (i.e., Bangladesh, Uganda, and India). The estimated effect of a 1-year delay in

menarche has varied from a 0.74- to a 0.30-year increase in marriage age in studies of Bangladesh, Uganda, and India.[2]

Early marriage, when instrumented by menarche, has been shown to be associated with lower education and employment for women in Uganda (Sunder, 2019), Bangladesh (Field & Ambrus, 2008), and India (Raj et al., 2015). A 1-year delay in marriage for women led to higher educational attainment, literacy, and employment in a study conducted in Uganda (Sunder, 2019). Later age at first marriage was found to be associated with more schooling and adult literacy for women in both Bangladesh and India (Field & Ambrus, 2008; Raj et al., 2015). One potential issue with this instrument is that several studies suggest that menarche may directly influence schooling due to lack of menstrual supplies or facilities (Adukia, 2017; Sommer, 2010; Mason et al., 2013; Sivakami et al., 2019).

This paper's two contributions are to (i) show the conditions under which menarche is a valid instrument for marriage age and (ii) demonstrate the external validity of the relationship between early marriage and women's education or employment. Using demographic health surveys funded by the U.S. Agency for International Development and the empirical strategy from research by Field and Ambrus (2008) on Bangladesh and Sunder's (2019) work on Uganda, we test for external validity by measuring this relationship across 12 countries in Africa, the Middle East, and Central Asia. We find the expected positive and significant relationship between menarche and marriage age in the pooled sample, with a 1-year delay of menarche being associated with a roughly 0.25-year delay in marriage. This is lower than other estimates from the literature from Uganda, Bangladesh, and India. We find that age at menarche is

[2] The estimated coefficient of menarche on marriage age is listed for each of the relevant studies: 0.74 (Field & Ambrus, 2008; Bangladesh), 0.40 (Asadullah et al., 2018; Bangladesh), 0.49 (Sunder, 2019; Uganda), 0.45 (Chari et al., 2017, India), 0.30 (Sekhri & Debnath, 2014; India).

statistically significant and positively related to marriage age in all but two of the countries studied (Turkey and Kyrgyz Republic). The null result of menarche in Turkey and Kyrgyz Republic may be due to the fact that women marry later and that puberty is not a binding constraint for marriage in these countries. We also show that menarche has a stronger effect on marriage age for women living in households with characteristics associated with early marriage: polygamous households, those in rural areas, and larger household size.

Our findings show a positive and statistically significant relationship between marriage age (instrumented by menarche) and education in all but one country, Botswana. In addition, there is a positive and significant relationship between marriage age and employment in a majority of the countries; however, in countries with higher women's employment, the results are less likely to be statistically significant. We also provide evidence that is consistent with menarche influencing marriage rather than education directly, as suggested by the work on menstrual supplies or facilities in schools. Finally, we replicate Sunder (2019) using the same Ugandan data in Appendix B, showing relatively consistent results.

Section 2: Conceptual Framework

The decision of when to marry in low-income countries is often not made by a woman herself, and many poor households are faced with incentives that encourage marriage at the earliest age possible (Parsons et al., 2015; Johnson et al., 2019). Marrying a daughter younger helps child brides gain some wealth from their husbands to take care of their own family, reducing the number of dependents in the household to be fed and clothed or receiving a bride price to support the rest of the family (Ahonsi et al., 2019; Tsekpo et al., 2017). Early menarche has been linked to a younger age of marriage across many individual case studies of countries

(Raj et al., 2015; Ibitoye et al., 2017; Field & Ambrus, 2008; Sunder, 2019). Traditionally in many countries, marriage comes only after menarche (Field & Ambrus, 2008; Tsekpo et al., 2017; Osei-Adu, n.d.; Ahonsi et al., 2019). In some cases, marriage occurs after children are conceived, which can only happen once a girl has entered puberty (Ahonsi et al., 2019). Parents marrying their daughter off closer to the age of menarche can help financially strained low-income households. Younger brides also receive higher bride prices, a given value placed on her reproductive capacity, virginity, and productive labor (Johnson et al., 2019).

The trends globally suggest that menarche age is declining, while the average age of marriage is increasing, suggesting that other factors (e.g., socioeconomic status) also influence marriage age. The average age of menarche fell from 14.7 in 1932 to 12.9 in 2002 (Leone & Brown, 2020). Improved socioeconomic status and nutrition have been linked to a younger age of menarche and global trends in socioeconomic status have been positive over the same period (Leone & Brown, 2020; Sunder, 2019; Field & Ambrus, 2008; Ibitoye et al., 2017). These trends suggest that to estimate the link between menarche and marriage age, researchers may need to control for socioeconomic and nutritional status, otherwise omitted variables may be a source of bias (e.g., economic status may bias the estimated relationship between menarche and marriage age toward zero). One way to control for economic status is to proxy nutrition. Sunder (2019) and Field and Ambrus (2008) proxied nutritional status using a woman's adult height.

A variety of settings using menarche as an instrument for marriage age have identified a positive link between later marriage and education. Marriage means a sudden change in rights and responsibilities for child brides, who are expected to undertake domestic duties in the marital household and forgo their education (Asadullah, 2019). Many girls withdraw from school when they marry, leading to the conventional wisdom that later marriage may increase schooling. In

Uganda, postponing marriage by 1 year was associated with a 0.5- to 0.75-year increase in education and a 10% increase in female literacy (Sunder, 2019). In Bangladesh, postponing marriage to the legal minimum age of 18 led to an estimated 14.2% increase in average female schooling and an almost identical change in female literacy (Field & Ambrus, 2008). In India, girls who reached menarche at a younger age were more likely to be married before 18 and early menarche was associated with lower levels of education (Raj et al., 2015).

There is mixed evidence for the potential of early menarche to reduce schooling directly through missed school days or reduced enrollment. Surveys of adolescents from Kenya, Tanzania, and India suggest that menstruation reduces schooling in part due to lack of supplies and adequate bathroom facilities (Sommer, 2010; Mason et al., 2013; Sivakami et al., 2019). This result is further supported by an evaluation of a school toilet program that increased girls' enrollment in India (Adukia, 2017), though contrasted by Phillips-Howard et al. (2016), who did not find a relationship between providing menstrual products and dropping out of school in Kenya. In India, Khanna (2021) found early menarche to be associated with lower school enrollment but not with daily attendance. Oster and Thorton (2011) found limited links in Nepal between early menarche and daily school attendance. Complicating the understanding of the causal pathways, Khanna (2021) pointed out that early menarche increases a girl's desire to be a housewife, so the decision for early marriage may be simultaneous.

Early marriage is also a barrier to paid employment (Grown et al., 2005). By dropping out of school to marry, young girls unable to obtain employable skills instead are confined to informal or home-based work (Ahonsi et al., 2019; Parsons et al., 2015). It is also possible that later marriage may encourage earlier entry into employment instead (Field & Ambrus, 2008). Marriage delay could potentially increase employment later in life and might have further effects

on employment and wages (Shareen & Paul, 2013). Finally, girls who marry early have limited decision-making power due to power imbalances within their marriage; this power reduction may decrease their labor force participation rate (Ahonsi et al., 2019; de Groot et al., 2018). Sunder (2019) found that postponing marriage by 1 year in Uganda implied an 8-percentage-point increase in employment. However, Dhamija and Roychowdhury (2020) and Agüero (2021) found no statistically significant relationship between employment and postponed marriage predicted by menarche in India and Colombia, respectively.

Section 3: Descriptive Statistics

The data used in the analysis come from surveys of 12 African, Middle Eastern, and Central Asian countries from demographic health surveys (DHS) administered by U.S. Agency for International Development. The surveys contain information on over 80,000 women from ages 15 to 49. The surveys are designed to be nationally representative, and the respondents are all women who have been married and are of childbearing age (15 to 49). DHS surveys are administered across the globe in low-income countries, but most do not ask about the age of menarche, so we are unable to include this information in the analysis. We elected to limit the sample to African, Middle Eastern, and Central Asian countries because (i) it allows for comparison across similar countries and climates and (ii) it made the analysis more manageable.

Table 1 reports that the average age of menarche was just under 14 years old, ranging from 13.1 years in Egypt in 1988 to 15.6 years in Botswana. The average age of marriage was just under 18 years old, which shows child marriage is quite common in many of these countries, ranging from an average of 16.1 in Yemen in 1992 to 20.7 in Botswana. Child marriage is quite common with between one-third and fourth fifths of respondents marrying before age 18 (see

Table 2). Although the surveys found an average of only 3 years of education, the range is large: from 1 year in Senegal in 1988 to 11 in the Kyrgyz Republic in 1997. Employment also varies substantially and does not seem to be related to other variables.[3] Finally, we use women's final height, when available, which averages 157.5 centimeters, with variation of no more than 6 centimeters among countries.

Table 1: Descriptive Statistics by Survey

Country	Year of survey	Average Menarche Age	Average Marriage Age	Average Women's Education Years	Average Employment	Height in CM
Senegal	1986	14.5	17	1.01	0.28	N/a
Yemen	1992	13.9	16.1	1.19	0.145	N/a
Yemen	2013	13.8	17.5	2.12	0.11	154
Morocco	2003-04	13.7	19.5	2.64	0.159	159
Egypt	1988	13.1	18.2	3.86	0.127	N/a
Cameroon	1991	14	16.6	4.3	0.574	N/a
Ghana	1998	15.1	18.6	4.33	0.834	159
Uganda	2001	14.4	17.4	4.47	0.782	158
Egypt	1992	13.2	18.7	4.53	0.21	N/a
Egypt	1995	13.2	18.6	5.01	0.166	157
Gabon	2000	14	18.1	6.17	0.473	158
Botswana	1988	15.6	20.7	6.22	0.314	N/a
Turkey	2013	13.2	20.1	7.2	0.533	158
Uzbekistan	1996	14.1	19.7	10.6	0.45	160
Kyrgyz	1997	14.6	19.9	10.8	0.432	158
	Averages	**14.0**	**17.7**	**3.2**	**0.36**	**157.5**

Child marriage before age 18 is relatively common in all the countries surveyed, ranging from 34% in Kyrgyz Republic to 79% in Yemen in 1992. The share of women married under 16 has a wider range: only 1% of Kyrgyz Republic and close to 54% in Yemen in 1992. When few women marry before 16, menarche is less likely to be a binding constraint on marriage, as

[3] Employment is defined as having worked for pay in the previous 2 weeks before the survey was administered.

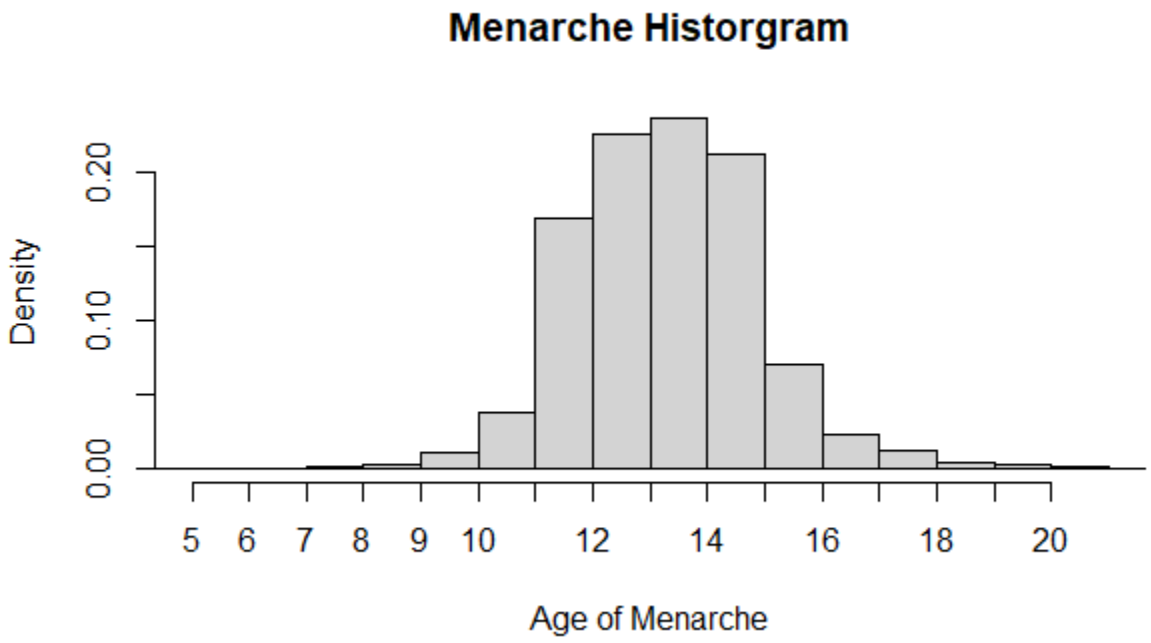
roughly 90% of those surveyed in Africa and 95% of those in Middle East or Central Asia reached menarche before age 16.

Table 2: Average Number of Women Married before 16 and before 19

Country	Married under 16	Married under 19
Kyrgyz Republic	1%	34%
Uzbekistan	2%	36%
Botswana	9%	37%
Turkey	9%	39%
Ghana	17%	55%
Morocco	18%	49%
Egypt92	22%	54%
Egypt95	23%	55%
Egypt88	28%	60%
Uganda	29%	71%
Gabon	30%	61%
Yemen13	33%	67%
Cameroon	43%	78%
Senegal	48%	82%
Yemen92	54%	79%

The average age of menarche in the sample was just under 14 years; the histogram in Figure 1 shows that menarche is roughly normally distributed for the whole sample. Age of menarche is a recall question at the time of the survey (we discuss potential for recall bias in the econometric section). The standard deviation in the sample was 1.57 years, with over 97% of the sample reporting menarche between the ages of 11 and 17.

Figure 1: Age of Menarche Histogram, Full Sample



We graph the average age of marriage for each menarche age, separating the sample into two groups: those with higher and lower marriage rates for 16 and under, where menarche potentially could bind the marriage decision. In countries with higher rates (at least 10%) of marriage before age 16, the interaction between menarche and age of first marriage exhibits an upward trend, suggesting the two are linked (Figure 2a).[4] With the exception of Yemen, these countries are all in Africa. In countries with lower rates of child marriage, the relationship is not evident (Figure 2b). The steeper upward trend in Figure 2a than in Figure 2b suggests that when average menarche age is closer to average marriage age, the two are more closely linked, we find results in the econometric analysis consistent with these graphs.

[4] So that each data point represents a sufficient sample, we limit the figures on menarche and average age of marriage from 11–17 years old for menarche, which covers 97% of women in the sample.

Figure 2A: Menarche and Age of First Marriage in Countries with High Child Marriage

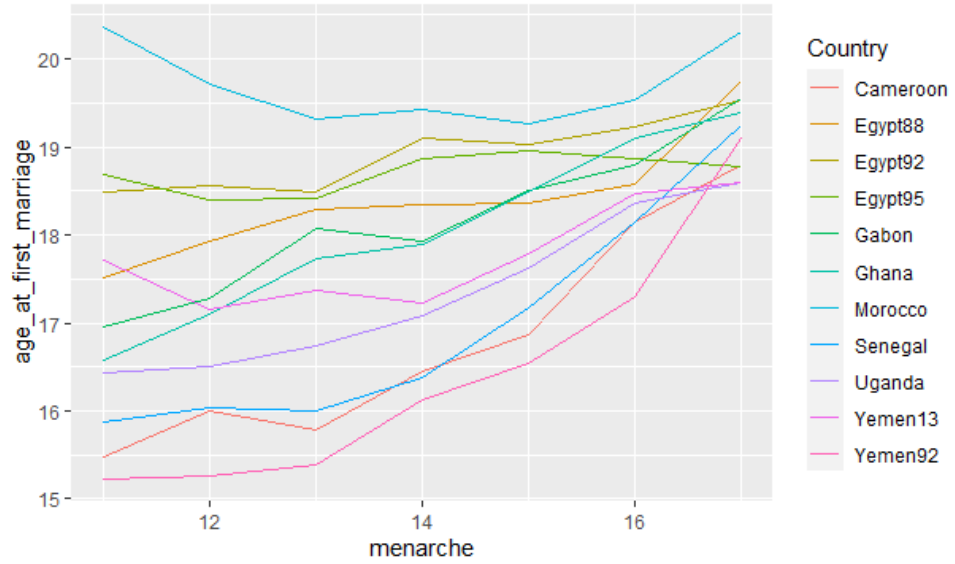
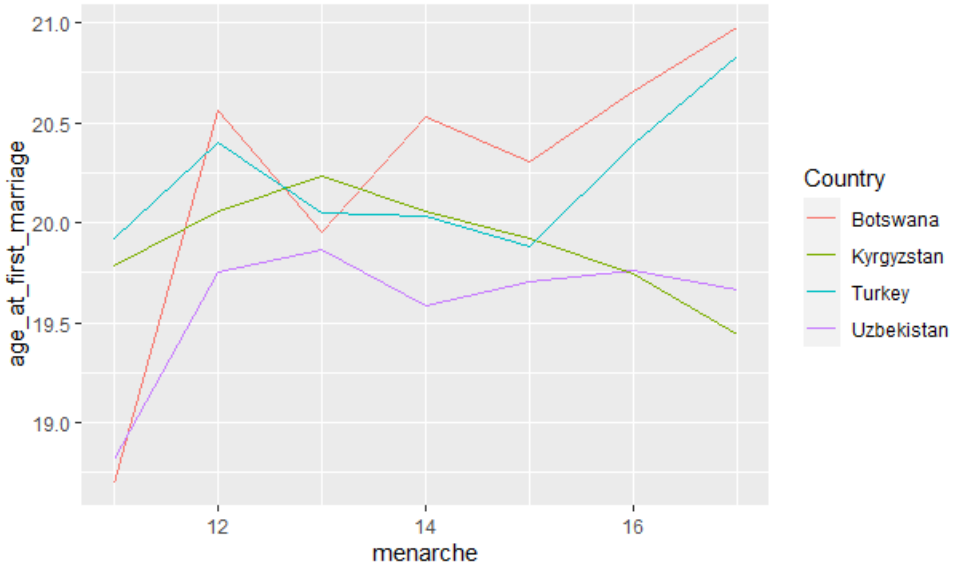


Figure 2B: Menarche and Age of First Marriage in Countries with Low Child Marriage



Section 4: Econometric Model

The econometric estimation uses a two-stage least squares (2SLS) model that mirrors previous work (Sunder, 2019; Fields & Ambrus, 2008). In the first stage, age at first marriage (*Age of First Marriage*) is predicted using menarche age (*Menarche*) and a set of controls

(*Controls*). In the second stage, education or current employment is estimated using *Controls* and the predicted value of age of marriage from the first stage $\left(\widehat{Age\ of\ Marriage}\right)$. All analysis takes place using the individual woman as the unit of observation. For ease of interpretation of coefficients and to parallel the previous literature (Sunder, 2019; Fields & Ambrus, 2008), we estimate regressions using 2SLS, where the second stage is a linear probability model.

Field and Ambrus (2008) established menarche as a potentially valid instrument because its main source of variation is genetic. Of particular importance is a study by Kaprio et al (1995) that shows that the correlation of menarche is three times higher for identical twins than for fraternal twins. Agüero (2021) showed that menarche age in Colombia is unrelated to adolescent health. The inclusion of height as a control seems to have little impact on the relationship between menarche and marriage age (Field & Ambrus, 2008; Sekhri & Debnath, 2014). Finally, Field and Ambrus (2008) provided evidence that recall bias is unlikely to affect the estimates as menarche has shown little evidence of recall bias in the medical literature; in many cultures, menarche is a time when girls may change their way of dressing or behavior in society, so the age is likely to be remembered.

First Stage: $\widehat{Age\ of\ Marriage} = \alpha_0 + \alpha_1 Menarche + \alpha_2 Controls + e_1$

Second Stage: $Education/Employment = \beta_0 + \beta_1 \widehat{Age\ of\ Marriage} + \beta_2 Controls + e_2$,

where *e* is an error term.

We begin by examining the first stage with a dataset of all the countries pooled into a single sample. We include survey fixed effects to control for variation between countries (and survey years with multiple surveys). We include additional individual/household level controls that are available in all the datasets (polygamous households, number of household members, rural/urban, current age, and the respondents' adult height when available). We rerun the model

with one interaction between each individual control and menarche to test in which cases menarche is most strongly related to marriage age.

We then estimate the models separately by DHS survey country and year, with additional individual controls when available, to see variation in menarche effect on marriage by country. Other country-specific controls are her religion, ethnic group, and subnational unit (e.g., province, state, or region), and an asset measure. There are slight variations in controls depending on the availability of data (see Appendix A for more information). It is worth noting that the DHS surveys are typically representative at both the national and province level.

We also test the potential for menarche to directly influence education by estimating this relationship for women who married at least 3 years after menarche. If menarche has a direct effect on education outside of the early marriage channel, as suggested by Khanna's (2021) evidence on enrollment, we may expect to see early menarche limit school for women who marry later. We limit the sample to women with the highest potential for education to be affected by menarche, those with 4–10 years of school. The range of education years was chosen as most countries roughly start education at age 6 or 7 and 90% of women experience menarche between 11 and 16 years of age, when they would be in late primary or early high school. We compare the direct relationship for women married at least 3 years after menarche to those married 0–2 years after menarche.[5] The estimates include country year fixed effects and errors are clustered at the survey level:[6]

Direct Relationship: $Education = \gamma_0 + \gamma_1 Menarche + \gamma_2 Survey + e_1.$

[5] 5% of the sample of women with 4–10 years of schooling married before reaching menarche. Roughly 25% married 0–2 years after menarche, with the rest marrying 3 or more years after menarche.
[6] In this case, survey fixed effects are country/year fixed effects, where Egypt and Yemen have multiple observations.

Section 5: Results

The first stage shows a strong positive connection between the age of menarche and the age of first marriage in the pooled sample and in most countries, particularly those with lower average marriage ages. We estimate that an additional year of menarche delays marriage by roughly 0.25 years in the full pooled sample or just over 0.17 years in the sample using height measurements. When using the pooled sample of countries with height measurements, including or excluding height as a control does not substantially affect the point estimate of menarche on marriage age. Menarche has a stronger effect on marriage in households that are polygamous, live in rural area, or have more members. The effect size is slightly smaller for older women.

We then provide separate estimates by country, finding that the relationship between menarche and marriage is generally strongest in countries with lower average marriage ages. In the second stage, education also is strongly linked to delayed marriage in most countries, but the range of estimates is much larger. Finally, the link between employment and delayed marriage is found in a majority of countries, though the relationship is not as strong as the one found for employment.

In the pooled sample of all the surveys, we estimate that an additional 1-year delay in menarche increases expected marriage age by 0.245 years (Table 3, model 1), which is statistically significant at the 1% level. To include a woman's current height to proxy her nutrition and wealth the sample size reduces by roughly 30,000 observations (out of 80,000 in the full sample), with five surveys being dropped. The coefficient of menarche on marriage falls to 0.178 for the sample with height measurements. Including or excluding the height variable as a control makes no substantial difference in the main coefficient of interest, menarche, consistent with previous finding discussed above (see Table 3, models 2 and 3). In the first two models,

which differ on the inclusion of height and the sample, the F-stats of excluding menarche are well above the standard 10 for an instrument (612 and 229).

Returning to the full pooled sample, in separate models with one interaction term apiece we find that polygamous households and rural households have a stronger coefficient of menarche on marriage, with an additional year of menarche corresponding to an increase marriage age closer to 0.39 and 0.35 years for polygamous and rural households, respectively, compared to monogamous or urban households (see Table 3, models 4 and 5). Finally, the interaction terms suggest larger households and younger women have stronger relationships between menarche and marriage age (see Table 3 models 6 and 7).

Examining the control variables in the prediction of marriage age we find that polygamous, rural, and larger households and women who are younger and shorter get married earlier. Most of these results like reflect norms and poverty that lead to younger marriage ages for polygamous, rural households and shorter women. Women in polygamous households have an average marriage age roughly 0.25 years younger than those in monogamous households, while women from rural households marry 1.5 years younger than those from urban households.

Women who are taller, live in smaller households and older marry later. For each additional decimeter of height, women marry 0.002 years later, with 1 standard deviation of height increasing marriage age by 0.134 years (SD = 67 decimeters). For each additional household member, women marry roughly 0.1 years earlier. Surprisingly, older women marry later. This may reflect the fact that women who marry younger have higher mortality rates, thus making it look like the older women who have survived marry later.

Table 3: Pooled Sample First Stage

	Age at First Marriage (First Stage)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Menarche	0.245***	0.178***	0.174***	0.241***	0.117***	0.084***	0.427***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.04)
Polygamous	-0.246**	0.011	0.004	-2.296**	-0.250**	-0.271**	-0.232**
	(0.11)	(0.15)	(0.15)	(0.90)	(0.11)	(0.11)	(0.11)
Rural	-1.513***	-1.227***	-1.204***	-1.512***	-4.569***	-1.502***	-1.509***
	(0.03)	(0.04)	(0.04)	(0.03)	(0.26)	(0.03)	(0.03)
Household Size	-0.092***	-0.108***	-0.108***	-0.092***	-0.091***	-0.395***	-0.092***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.03)	(0.00)
Current Age	0.053***	0.071***	0.071***	0.053***	0.053***	0.053***	0.131***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.015)
Height			0.002***				
			(0.00)				
Menarche*Poly				0.144**			
				(0.06)			
Menarche*Rural					0.223***		
					(0.02)		
Menarche*Size						0.022***	
						(0.00)	
Menarche*Age							-0.006***
							(0.00)
Constant	16.429***	15.772***	12.446***	16.485***	18.238***	18.705***	13.924***
	(0.19)	(0.17)	(0.45)	(0.19)	(0.24)	(0.29)	(0.52)
N	80,241	50,233	50,233	80,241	80,241	80,241	80,241
Sample	Full	Height only	Height only	Full	Full	Full	Full
Adjusted R^2	0.127	0.123	0.125	0.127	0.129	0.129	0.128

*p**p***p<0.01. Survey fixed effects are included in the estimation but omitted from the table for readability. The F-stat for the excluded regressor (menarche) for models 1 and 2 are 611.75 and 228.75, respectively.

We now estimate the relationship between menarche and marriage age separately for each survey (Table 4). We find that marriage age is positively related to menarche in 11 of the 15 surveys, with a range of 0.216–0.495 (statistically significant at the 1% level) (i.e., a 1-year delay

in menarche increases marriage age by 0.2–0.5 years). The F-stat of the excluded regressor in the first stage is above 26 for all 11 surveys with statistically significant results, over twice the value of 10 suggested by Staiger and Stock (1997) for a weak instrument. All 11 of these countries have an average marriage age below 19. In Morocco and Uzbekistan, the relationship is also positive and significant at the 10% level, with coefficients of 0.06 and 0.07, respectively. Finally, while Kyrgyz Republic and Turkey have positive coefficients on menarche, neither are statistically significant likely due to higher average age of marriage. The F-stat of the excluded regressor is similarly below the standard cut-off of 10.

Table 4: Coefficient on Menarche on Age of Marriage (First Stage)

Country	Menarche Age	SE	Average Marriage Age in Country	F-stat of Menarche in the First Stage
Yemen92	0.460***	(0.04)	16.1	162.8***
Cameroon	0.450***	(0.04)	16.6	150.92***
Senegal	0.495***	(0.09)	17.0	30.6***
Uganda	0.426***	(0.03)	17.4	160.9***
Yemen13	0.300***	(0.02)	17.5	175.8***
Gabon	0.339***	(0.07)	18.1	26.9***
Ghana	0.471***	(0.05)	18.6	99.4***
Eygpt95	0.216***	(0.03)	18.6	50.5***
Egypt92	0.239***	(0.03)	18.7	28.2***
Egypt88	0.299***	(0.03)	18.2	78.874***
Morocco	0.057*	(0.03)	19.5	3.1
Uzbekistan	0.072*	(0.04)	19.7	3.8
Kyrgyz	0.034	(0.04)	19.9	0.8
Turkey	0.055	(0.04)	20.1	2.3
Botswana	0.363***	(0.07)	20.7	30.0***

Note: See Appendix A for details on variables included. When available, controls include woman's height, region, religion, ethnic group, number of household members and measure of wealth. *** p < .01 ** p < .05 * p <.1

The predicted positive relationship between marriage age and education is found in 14 of the 15 countries. Table 5 reports the results of the second-stage estimation of the relationship between predicted marriage age based on menarche and controls in the first stage. Consistent

with the theory that, when menarche is binding for marriage and school age, the effects of delayed marriage will be largest in place where girls attend 4–10 years of school. In these countries, the effect of delaying marriage by a year is associated with 0.10–0.78 more years of school (Gabon and Uganda). We find that delayed marriage tends to have the smallest impact in countries with lower years of education (i.e., Senegal and Yemen), though statistically significantly, each year of delayed marriage adds only 0.005–0.02 years of schooling. We still see the impacts in the predicted direction in countries where the first stage was not statistically significant.

The one puzzle is that Botswana has a negative and statistically significant relationship between marriage age and schooling. Botswana is an outlier in terms of marriage age in Africa. The median age of marriage in the 1988 survey was higher than in France and the United States (Singh & Samara, 1996). The counterintuitive result may be due to the fact that Botswana had a large portion of male migrants influencing the labor market, influencing the marriage decision (Singh & Samara, 1996).

Table 5: Predicted Marriage Age and Education Years

Country	Predicted Marriage Age	Se	Average Education Years
Senegal86	0.021***	(0.01)	1.01
Yemen13	0.005***	(0.00)	2.12
Yemen92	0.008***	(0.00)	2.12
Morocco	0.240***	(0.01)	2.64
Cameroon	0.265***	(0.02)	4.3
Ghana	0.159***	(0.02)	4.33
Uganda	0.780***	(0.09)	4.47
Egypt88	0.476***	(0.01)	4.53
Egypt92	0.520***	(0.01)	4.53
Egypt95	0.573***	(0.02)	4.53
Gabon	0.106***	(0.02)	6.17
Botswana	-0.307**	(0.15)	6.22
Turkey	0.247***	(0.01)	7.2
Uzbekistan	0.178***	(0.01)	10.6
Kyrgyz	0.200***	(0.01)	10.8

Note: See Appendix A for details on variables included. When available, controls include a woman's height, region, religion, ethnic group, number of household members, and measure of wealth. Second-stage estimation based on first stage results in Table 3.
*** p < .01 ** p < .05 * p <.1

We find that the relationship between menarche and education is stronger for girls who marry shortly after reaching puberty. As mentioned above menarche may reduce schooling directly and not through marriage if girls drop out due to lack of menstrual supplies or bathroom facilities. To identify the effect of menarche on education directly in this manner we examine girls separately who marry three years after reaching menarche. We look specifically at women who have had 4–10 years of school when menarche is potentially experienced in the sample (e.g., ages 11–17), assuming a starting school age of 6 or 7. For women married at least 3 years after menarche, the relationship between menarche age and education is not statistically significant (Table 6, column 2). For women married within 2 years of puberty, an additional 1-year delay in menarche is associated with roughly 0.1 more years of school (Table 6, column 1). If bathrooms or supplies were responsible for these results, we would expect similar coefficients

for women who married later. These results suggest that girls who marry close to puberty—rather than girls who leave school when reaching menarche because of lack of bathrooms or supplies—are driving these results. That menarche has stronger impacts on education for girls who get married within 2 years of menarche age supports the conclusion that marriage (and not lack or supplies or facilities) drives the results, though this is not definitive.

Table 6: Pooled Sample Menarche Age and Education Direct Estimate

Years between Menarche and Marriage	0–2	3 or More
Menarche	0.106***	0.0109
	(0.0246)	(0.0128)
Observations	4,810	14,641
R-squared	0.394	0.453

Note: Pooled sample of all countries with data limited to women with 4–10 years of education. Includes country/year fixed effects, which are omitted for readability. Values in parentheses are robust standard errors clustered at the survey level. *** p<0.01, ** p<0.05, * p<0.1

The final analysis examines marriage age and employment (Table 7). We find the expected positive relationship in most countries. In 11 of the 15 survey populations, the coefficient of predicted marriage age based on menarche is positively related to employment by a statistically significant amount. For these 11 surveys, the range of roughly of coefficients is a roughly 0.5- to 2.5-percentage-point increase in employment for each year's delay in marriage. The coefficients are stronger where women are less likely to be employed. In Ghana and Uganda, where roughly 80% of women are working, a delay in marriage age does not have a statistically significant effect on employment.

Table 7: Predicted Marriage Age and Employment

Country	**Predicted Marriage Age**	SE	% of Women Working
Yemen92	0.008***	(0.001)	11%
Egypt88	0.025***	(0.001)	13%
Yemen13	0.005***	(0.001)	15%
Morocco	0.012***	(0.001)	16%
Egypt92	0.020***	(0.001)	17%
Egypt95	0.026***	(0.001)	21%
Senegal86	-0.001	(0.001)	28%
Botswana	0.009	(0.018)	31%
Kyrgyz	0.017***	(0.003)	43%
Uzbekistan	0.018***	(0.003)	45%
Gabon	0.013***	(0.003)	47%
Turkey	0.010***	(0.001)	53%
Cameroon	0.008**	(0.003)	57%
Uganda	0.003	(0.010)	78%
Ghana	-0.002	(0.002)	83%

Note: See Appendix A for details on variables included. When available, controls include a woman's height, region, religion, ethnic group, number of household members, and measure of wealth. Second-stage estimation based on first stage results in Table 3. *** p < .01 ** p < .05 * p <.1

Section 6: Conclusion

The paper's core contribution is to demonstrate that menarche, the age of a girl's first menstrual period, is positively related to her age of marriage in many cases, supporting the external validity of using menarche as an instrument for the age of marriage in some contexts. The estimate of the effect of menarche on marriage age is smaller in our full sample than in previous studies in Bangladesh, India, and Uganda and even smaller when restricted to surveys that include mothers' height. We show that the relationship between menarche and marriage age weakens in countries where the average age of marriage is higher, consistent with the mechanism that puberty works as a binding minimum constraint for the age of marriage. We also show that delaying marriage is positively associated with both women's education and employment across Africa, the Middle East, and Central Asia. Finally, we provide evidence that suggests that the effect of menarche on education is through marriage and not through reduced schooling due to lack of menstrual supplies for facilities.

One limitation of the data is the age of some of the datasets. It is unclear whether international trends in the increasing the age of marriage have weakened the relationship between menarche and age of first marriage. This relationship may be further weakened as the age of menarche falls with improving nutrition, widening the gap between menarche age and marriage. A second limitation is that some of the DHS datasets lack data, particularly women's height. Though we mostly use the same variables across the different surveys there is some variation, as shown in Appendix A. A third limitation is the potential for menarche to influence education directly through school enrollment, as suggested by work in India (Khanna, 2021); however, survey responses from the same study suggest that early menarche is also linked to increasing aspirations to be a housewife.

This research adds to the evidence base in favor of policies aimed at delaying marriage for girls to positively impact both their education and employment. The results suggest that policies such as cash transfers targeted to young women who stay in school (Baird et al., 2010), enforced minimum marriage age laws (Arthur et al., 2018), and nudges toward delaying marriage (Dupas, 2011) would improve education and employment, particularly in countries where the average age of marriage is lower.

Three potential pathways could be taken to extend the analysis. The first is to use DHS surveys to examine other regions, such as the Latin America and the rest of Asia. A second pathway would be to compare how the estimates of delayed marriage using menarche compare to those from other mechanisms such as nudges or bans on child marriage. A third extension would be to examine child outcomes in the way that, for example, Sunder (2019) examined the anthropometrics of women's children. Work by Nepal (2018) and Hossain (2020) suggests that a woman's education is a key link to her children's nutrition outcomes, so there may be further generational effects of early marriage.

Appendix A

The DHS asks roughly the same questions in all countries surveyed. In Botswana, we were unable to find regional controls. In about half of the surveys, women's height was unavailable, though this did not seem to influence the results. Religion and ethnic groups are unavailable in some populations with heterogeneous populations. Table A lists the variables used in each regression.

Table A: Control Variables Used in First and Second Stages

Country	Year of survey	Controls
Senegal	1986	woman's region, religion, ethnic, number of and household members
Yemen	1992	woman's region, and number of household members
Yemen	2013	woman's height, region, and number of household members
Morocco	2003–2004	woman's height, region, and number of household members
Egypt	1988	woman's region, religion, and number of household members
Cameroon	1991	woman's region, religion, ethnic group, and number of household members
Ghana	1998	woman's height, region, religion, ethnic group, and number of household members
Uganda	2001	woman's height, region, religion, and number of household members
Egypt	1992	woman's region, religion, and number of household members
Egypt	1995	woman's height, region, religion, and number of household members
Gabon	2000	woman's height, region, religion, ethnic group, number of household members
Botswana	1988	woman's religion, ethnic group, and number of household members
Turkey	2013	woman's height, region, and number of household members
Uzbekistan	1996	woman's height, region, religion, ethnic group, number of household members
Kyrgyz	1997	woman's height, region, religion, ethnic group, and number of household members

Appendix B: Comparison to Sunder

The paper approximately replicates Sunder's (2019) analysis of these relationships in Uganda using the same DHS data with some minor adjustments. Our findings are roughly similar to Sunder, though we find one potential minor error in Sunder's analysis. We requested the replication files from the author and received code to replicate the regressions (i.e., a Stata .do file) but not the code to create the specific sample used in Sunder's analysis from the original DHS datasets. The author was not able to locate the code to create the dataset used in the regressions, so we attempted to clean the data on our own. Three coefficients estimated in this paper have similar results in Sunder (2019): menarche's effect on marriage age, estimated marriage age on education, and estimated marriage age on employment.

We find that a 1-year delay of menarche increases marriage age by 0.43 years, which almost matches Sunder's coefficient of 0.45 in model 4 (Table 1). When we attempted to replicate Sunder's analysis with our data cleaning, the coefficient was substantially different (0.03). We believe one potential issue to be a minor error: Sunder (2019) suggested that the age of first sexual intercourse was included in the estimation (see Sunder, 2019, Table 1 footnote). We believe that this variable was likely excluded because of the high correlation between the age of first sexual intercourse and marriage age (0.6), leading to multicollinearity. When we omitted the age of sexual intercourse as a control, we obtained estimates of the effect of menarche age on marriage age not substantially different than Sunder, as noted above. We corresponded with the author pointing out the potential issue. Sunder responded that the note about the inclusion of age at first sexual intercourse was added in a revision, but the regression likely did not include the age of first intercourse for the reasons we suggested. In other words, the result is not meaningfully different once a minor correction was made.

In terms of the second coefficient on the expected age of marriage's effect on education are extremely similar. Our model finds an additional delayed year of marriage increasing schooling by 0.78 years compared to Sunder's finding of 0.75 years, with the same level of statistical significance. Our findings on the effect of marriage age on employment are not statistically significant, with a 1-year delay in marriage increasing employment by 3 percentage points compared to 8 percentage points in Sunder (2019). We tried the estimations both including and excluding age of first intercourse as a control and were unable to find statistically significant results that replicate Sunder. Overall, however, the similarity in coefficients between our analysis and Sunder's suggests that overall conclusions hold after the replication once age of sexual intercourse is excluded.

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