Marrying Young: The Surprising Effect of Education

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Job market paper

Abstract

In a traditional marriage market, family's preferences and beliefs over bride types play a significant role in matching. In this paper, we study how an exogenous increase in female education, a preferred attribute in the marriage market, affects her age at marriage. The District Primary Education Program (DPEP) launched in India in 1994, provides a regression discontinuity set-up to estimate the causal impact of education. Using Demographic Health Survey (DHS) 2015-16 data, we find that the program leads to an increase in women's education by 0.8-1.5 years. Next, to see the impact of education on age at marriage, we use the program cut-off as an instrument for education. In contrast to the literature, we find one year increase in education leads to decrease in age at marriage by 0.44 years. Using a simple transferable utility model, we provide a framework for a negative relationship between education and the age at marriage. As educated and young brides are more desirable in the marriage market, educated women are cleared from the marriage market before less educated women. Further, we find that an increase in education leads to a stable match. Finally, we check if the effect of education on age at marriage varies by the availability of an outside option in the labor market. Our results indicate that educated women in high-wage districts on average marry later than the low-wage districts. A 100 rupee increase in women's wages (25 percent of weekly income) leads to a delay in the age at marriage for educated women by 0.1 years.

Keywords: Education, marriage market, age at marriage
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1 Introduction

Early marriage is still a common practice in many developing countries. In 2015, nearly 27% of Indian women aged 20-24 were married before the legal age of 18 (DHS, 2017). Child marriage can have negative consequences on women's health and economic outcomes. (Chari et al., 2017; Corno, Hildebrandt, & Voena, 2020; Field & Ambrus, 2008; Jensen & Thornton, 2003). Studies have shown that education can increase women's age at marriage through increased labour market prospects (Chiappori, Iyigun, & Weiss, 2009; Heath & Mobarak, 2015; Jensen, 2012). However, the positive association between education and age at marriage is not obvious when (a) perceived labor market returns to women's education are low or (b) preferences and beliefs in the marriage market are gender-biased (Buchmann et al., 2021; Jayachandran, 2021). Hence, more evidence is required to understand the relationship between female education and age at marriage.

In this paper, we estimate how an increase in women's education affects their age at marriage in the context of India. In theory, female education can affect their age at marriage through the matching on local marriage markets and the preferences of men and women (Chiappori, Dias, & Meghir, 2018). In India, majority of marriages are arranged by parents where preferences and beliefs play a significant role in finding a match in the marriage market. For instance, women's family prefer a groom with high income. According to Adams and Andrew (2019), parents believe that the chance of a poorly educated daughter receiving a marriage offer from a "high quality" groom with a government job is very low. Therefore, one of the main reasons parents invest in their daughter's education is to increase her gains from marriage. Men's family, on the other hand prefer a younger bride due to lesser autonomy and perceived high quality (Anukriti & Dasgupta, 2017). Also, education of women is a desirable attribute in the marriage market due to the inter-generational transmission of health and education (Chen & Li, 2009; Rosenzweig & Wolpin, 1994; Thomas, Strauss, & Henriques, 1991). In such a setting, we investigate how an exogenous increase in education, a preferred attribute of women in the marriage market, affects her age at marriage.

To causally estimate the relationship between women's education and their timing of marriage, we exploit the quasi-random variation in schooling induced by a large-scale education program in India, District Primary Education Program (DPEP). The policy aimed to increase access to primary schooling and reduce the gender gaps in education. DPEP targeted low literacy districts by building schools, hiring teachers, and upgrading infrastructure (Jalan & Glinskaya, 2002). Districts, where the average female literacy rate was below the national average of 39.3 (Census 1991), were eligible for program benefits. We exploit this discontinuity around the cut-off using regression discontinuity framework similar to Khanna (2015).

We find that the program leads to an increase in women's education of around 1.48 years. Our estimates are comparable to Sunder (2020), who also finds that the program increased women's education by around 0.8 years. Another study by Akresh, Halim, and Kleemans (2018) on the long-term effect of the school construction program in Indonesia, finds an average effect of 0.46 years of education for women in the treated district. We are estimating a local average treatment effect (LATE) for those districts around the cut-off who were induced into taking the program as opposed to the average treatment effect. This could explain the large effect in our study.

Next, to causally estimate the impact of an increase in education on age at marriage we use the DPEP cut-off indicator as an instrument for education. We find that one year increase in women's education leads to a fall in their age at marriage by 0.44 years.[1] The average age at marriage in the comparable districts is 19.2. This suggests that one year increase in women's education reduces the average age at marriage to 18.75 years which is just above the legal age of 18. Our results are contrary to the existing evidence that finds a positive association between education and age at marriage (Breierova & Duflo, 2004; Brien & Lillard, 1994; Ikamari, 2005; Kirdar, Dayıoğlu, & Koç, 2009). From a policy perspective, increasing education alone might not help in delaying age at marriage for women. At times

[1]The identification assumption holds around the cut-off. There are 98 districts within the cut-off range of plus-minus 4.7 percent. Out of these 54 are below and 44 are above the cut-off.

policies can have unintended consequences for certain groups depending on the economic and social environment (Ashraf et al., 2020; Bau et al., 2020).

We explore probable mechanisms and provide a conceptual framework for the negative association between education and age at marriage in our context. First, we find that the negative results are more pronounced for women who live in districts with low wage rates (a proxy for opportunity cost of marriage) compared to those with high wage rates. We interact district wise average female wages with women's education using DPEP cut-off indicator as an instrument. We find that a 100 rupee increase in women's wages leads to an increase in age at marriage for educated women by 0.1 years compared to less educated women.

Second, the negative association between education is larger at median and higher levels of education. We perform IV quantile regression to study the distributional impact of education on age at marriage using the framework of Kaplan and Sun (2017). We find that the there is fall in age at marriage for mean and median level of education (8 years). At higher education quantiles there is further decrease in age at marriage.

To explain the empirical findings, we use a transferable utility framework in a unitary household model (Chiappori, 2020; Low, 2014). Under transferable utility framework a stable match can be established by maximising the sum of utilities of the partners. In our framework, men have one dimension of income and woman have two dimensions education and age. We assume men's utility to be decreasing in the age of the women due to their preference for a younger bride. Men value the quality of their children which is increasing in their wife's human capital. In such a context, a stable match at equilibrium implies a negative association between women's education and age at marriage. Given that more educated and younger brides are more desirable on the marriage market, women who have more education improve their returns on the marriage market as they are cleared from the market before less educated women.

Our theoretical framework shows that utility received by the spouses should be jointly higher than the surplus and that all the individuals receive positive benefit from marriage.

A stable match would therefore require an increase in the surplus for women. To check empirically if education leads to an increase in women's surplus in the marriage, we use DPEP cut-off indicator as an instrument for women's education. We then analyse if education leads to an improvement in women's post marriage well-being indicators such as domestic violence, household wealth, health-care access and decision making power in the household.

In the literature, divorce is used to indicate an unstable match. India has the lowest divorce rates in the world, (Jacob & Chattopadhyay, 2016), therefore, we cannot use it as an indicator of stability. Instead, we use post marriage domestic violence and health indicators to signal stability. We find a drop in the domestic violence experienced by women due to an increase in education. Next, we check how education affects wealth and healthcare access post marriage. In the matching framework there exits assortative matching on men's income and women education. We also find that educated women are more likely to be matched in the high wealth percentile households. Further, there is improvement in their health care access. Education leads to an increase in hospital deliveries, access to antenatal care and contraceptive use by 7 percent, 5 percent and 14 percent respectively. However, there is no change in decisions making power regarding spending their earnings and big household purchases. Overall, these indicators suggest an improvement in the well being of the educated women. This suggests that the match is stable as educated women have higher post marriage surplus as compared to uneducated women.

We perform several robustness checks for validity of our main estimate of age at marriage. First, we test whether the younger cohorts in the sample who are not yet married influence our estimate of age at marriage. In our main specification we use data on women in the age group of 15-40. In India, by the age of 25 more than 96 percent of the women are married. Thus, we restrict the sample to the age group of 25-40 to include only women who have completed their marriage cycle. Table **??** shows the result using this restricted sample. We find the age at marriage falls in this sample as well.

Second, the DPEP program affected both men and women (Khanna, 2015). We want to check how the increase in men's education affected their age at marriage. Using similar IV specifications, we estimate the impact of an increase in education on partner's age at marriage. We find that the partner's age at marriage does not change due to an increase in education (table 11). This indicates that the impact is not a common trend for both men and women but it is specifically for women. Next, we restrict our sample to couples where only women were affected and men were not affected by the program. This allows us to isolate the effect of the program only through increases in women's education and not of men. These are men who were too old to change their schooling decision when the program was launched. On average, there is a 4-year difference between husband and wife's age in the sample. Thus, the restricted sample is not too different from an average couple in the full sample. Even in this sample, we observe a fall in the age at marriage for women.

Third, the IV method uses a fixed bandwidth from the first stage (table 5). To check the robustness of the estimate, we use various bandwidths. We find the impact of age at marriage is still negative and significant and does not vary with change in bandwidth size. Fourth, we also estimate the model using a difference-in-difference strategy. This estimation would allow us to capture the intention to treat the effect. Districts received the program at different years between 1994 to 2002. For each of the treatment years, we compare districts that received DPEP to districts that did not receive DPEP. The treated cohort is women who were 6-19 years of age when DPEP was implemented in their districts and the control cohort is women who were too old to change their schooling decisions, hence, ages 20-30. We find that for every year of DPEP implementation, the age at marriage in DPEP districts decreases significantly for the treated cohort of women (shown in figure 6).

There exists mixed evidence on the causal effect of female education on age at marriage. On one hand Breierova and Duflo (2004), Brien and Lillard (1994), Ikamari (2005), and Kirdar, Dayıoğlu, and Koç (2009), find a positive association between education and age at marriage, while recent evidence from countries with stricter gender norms find no effect of increase in education on women's age at marriage (Khan, 2021; Lavy & Zablotsky, 2011).

Our paper adds to this literature by highlighting the role of preferences in the marriage market and low female employment rates due to gender biased norms (Buchmann et al., 2021; Dhar, 2021; Jayachandran, 2021). This paper is closely related to the literature on (a) factors that affect age at marriage (Corno, Hildebrandt, & Voena, 2020; Goldin & Katz, 2002) and (b) marriage markets in developing countries (Anukriti & Dasgupta, 2017; Banerjee et al., 2013; Beauchamp, Calvi, & Fulford, 2017; Chiplunkar & Weaver, 2021).

The rest of the paper proceeds as follows. Section 2 provides background information of the DPEP. Section 3 describes the data. In section 4 we present the conceptual framework. Section 5 and 6 provides the estimation strategy and results respectively. Section 7 concludes the paper by discussing the key findings and steps ahead.

2 District Primary Education Program (DPEP)

The District Primary Education Program (DPEP) is one of the largest donor assisted programs launched by the Government of India in the year 1994. The scheme was run in partnership with the central government, the state governments and external donor agencies. The main objectives of the program were to increase access and quality of primary education and reducing gender and socio-economic inequality. Financing of the program was based on a 85:15 ratio with 85 percent given as a grant to the states by the central government (in partnership with international development agencies, World Bank, ECU, DFID, UNICEF) and 15 percent contributed by the state governments. In order to avoid crowding out of government investment in elementary education, the state governments had to maintain at least their existing levels of expenditure on elementary education. Overall, the project lead to an increase in the total allocation by the government for elementary education by about 17.5 to 20 percent.

Apart from civil works the program interventions ranged from enrollment drives, community mobilization campaigns, establishing academic resource centers, to in service teacher training, textbook and curriculum renewal (Sipahimalani-Eao & Clarke, 2003). The program also focused on decentralised management of elementary education with districts as the main administrative unit. To ensure that a large part of the funds were spent directly on quality improvements, strict guidelines were laid regarding the proportions spent on civil works (24 percent) and management costs (6 percent) (Pandey, 2000). According to the 16th Joint Review mission (MHRD, 2002), DPEP covered around 51.3 million children and 1.1 million teachers in the school system. By the year 2002 around 86,850 new schools and 83,500 alternative school centers were set up.

An important feature of the program was that it was targeted to districts with poor educational outcomes. There were two main criteria which were used to select districts under the DPEP. First, the districts with female literacy rate below the national average of 39.3 were selected, and second, districts where the total literacy campaigns were successful. However, by 1994, the total literacy campaign had been implemented in almost all districts in India. Hence, the main selection criterion into DPEP was the national average female literacy rate. The program was introduced in four phases across the country. The total number of districts covered by all DPEP phases (1994-2002) was 242 (273 with bifurcated districts) covering 18 states of India.

Initial evidence showed that the program helped in improving access to primary education and progression into higher levels of education beyond primary (Jalan & Glinskaya, 2002). More recent studies provide evidence of the policy on education levels after the completion of the program. Azam and Saing (2017) use difference-in-difference method to estimate the impact of the policy on the probability of completed primary education and years of schooling. While, Khanna (2015) uses an Regression Discontinuity Design to estimate the general equilibrium (GE) effect of the policy on education and labor market outcomes. Both studies find a positive effect of the program on the years of schooling.

3 Data

For our analysis, we combine National Family and Health Survey (NFHS-4, 2015-16), the NSS employment and unemployment survey (2005), the District Information on Systems in Education (DISE 2005) and Primary Census Abstracts 1991 (Adukia, Asher, & Novosad, 2020; Jayachandran, 2017). The NFHS is a nationally representative survey carried out under the aegis of he Ministry of Health and Family Welfare (MoHFW), Government of India. The survey includes data on fertility, health, and family welfare for the country at individual level. The sample is generated using the stratified two-stage sampling method with the 2011 census as the sampling frame. Primary Sampling Units consists of villages in rural areas and Census Enumeration Blocks (CEBs) in urban areas (DHS, 2017). For our analysis we use the Women's Questionnaire with detailed information on women's background characteristics (age, literacy, schooling, religion, caste/tribes), marriage and fertility decisions. A total of 723,875 eligible women age 15-49 were identified for individual women's interviews. Interviews were completed with 699,686 women, for a response rate of 97 percent.

To get information on schools District Information on Systems in Education (DISE 2005) is used. We use aggregate district level data available from the DISE website for the years 2005. We also use primary census abstracts for the year 1991 to get information on district level literacy rates and sex ratios. Finally information on DPEP status was collated manually using various GOI review reports published by NEUPA to map the progress of DPEP over the years.

The target group of the program consists of women, below the age of 19 in 1994. In 2015, this corresponds to women below the age of 40. Thus, for our analysis we focus only on women below the age of 40. This provides us with a sample of 543,023 eligible women. Out of these, 358,303 women are married in the sample (69 percent) and 316,728 women have given birth to at least one child (60 percent). The average age of women in the sample is 26 years. The mean years of education is 7.5. In the sample, almost half of the women marry by the age 18 (average age at marriage for women is 18.5 years) and have their first child by age 20-21. Table 1 has detailed descriptive statistics for all variables including marriage, fertility, household indicators and surplus variables (women health access, domestic violence etc.). Table 2 has definitions of each variable used in the analysis.

4 Estimation Strategy

The decision of an individual to invest in education is correlated with various unobserved family, social and individual characteristics which might also effect their marriage and fertility outcomes. This makes it difficult to casually estimate the effect of education on marriage market outcomes. The District Primary Education Program (DPEP) provides a quasi-random variation in access to education that can be used to overcome the endogeneity of education. DPEP was targeted to districts with low educational outcomes. Districts with an average female literacy rate below the national average of 39.3 (Census 1991) were eligible to get funding under the program. We first estimate the effect of the program on years of education using regression discontinuity framework similar to Khanna (2015). The identification of the causal effects of DPEP program comes from the assumption that all other factors determining the outcomes are continuous with respect to female literacy (Lee & Lemieux, 2010; Van der Klaauw, 2008).

There is imperfect compliance to DPEP on female literacy rates. It was found that not all districts below the cut-off got the treatment while some districts that were not eligible (i.e above the cut-off) received the treatment. In a setting of imperfect compliance a fuzzy regression discontinuity design can be applied to estimate treatment effects. We estimate the first stage relationship between the running variable and treatment status in the close neighbourhood of the centered female literacy rate using equation 1 below.

$$T_{id} = \alpha + \gamma 1[X_d \leq c] + f(X_d) + \epsilon_{id}, \qquad c - h \leq X_d \leq c + h \tag{1}$$

where X_{id} is the centered assignment variable (39.3 - district female literacy rate). T_{id}

is a dummy which takes value 1 if the individual belongs to a district which got DPEP. $1[X_d \leq c]$ is a deterministic and discontinuous function of female literacy rate that equals 1 if the centered female literacy rate of district d is below 0 (below 39.3 district female literacy rate) and 0 otherwise; $f(X_{id})$ is a function used to flexibly model X_{id} and allowing for different slopes on different sides of the cutoff; h_n is selected using mean square error (MSE-RD) optimal bandwidth (Calonico et al., 2017).

In the second stage we estimate equation 2,

$$Y_{id} = \beta + \tau_{FRD}\hat{T}_{id} + g(X_d) + \varepsilon_{id}, \quad c - h \leq X_d \leq c + h \tag{2}$$

where Y_{id} is either age at marriage of the women or other marriage market outcomes; $\hat{T}_{id}$ is the estimated probability of treatment from the first stage; τ_{FRD} is the main coefficient of interest which gives us the impact of DPEP on the outcome variable; $g(X_d)$ is a polynomial controlling for smooth functions of female literacy rate in district d and allowing for different slopes on different sides of the cutoff to account for the conditional expectation of the outcome.

The regression discontinuity specification in equation 2 measures the effect of the DPEP program on education and age at marriage. However, our main question is to estimate the effect of education on the age at marriage and not the DPEP program. The DPEP assignment rule can be used as an instrument to identify the causal effect of education. We create an indicator variable which takes value 1 if the district is below the average literacy cut-off and 0 otherwise.

The 2-SLS approach is shown in the equations 3 and 4 below:

$$Educ_{id} = \delta + \theta 1[X_d \leq c] + f(X_d)\epsilon_{id}, \quad c - h \leq X_d \leq c + h \tag{3}$$

$$Y_{id} = \zeta + \tau_{IV}\hat{Educ}_{id} + g(X_d) + \varepsilon_d, \quad c - h \leq X_d \leq c + h \tag{4}$$

In equation 3, the instrument $1[X_d \leq c]$ captures the discontinuity in the relationship between education $Educ_{id}$, and district female literacy rate $f(X_d)$. Since this discontinuity is the source of exogenous variation in education, the analysis is carried out only for districts in the close neighbourhood of the cut-off. In equation 4, $Ed\hat{u}c_{id}$ is the estimated exogenous change in education. τ_{IV} is the main coefficient of interest which gives us the impact of education on the outcome variable.

4.1 Validity checks

In figure 1, we first show a discontinuity in receiving the treatment on the centered female literacy rate at the cut-off. The districts lying in the close neighbourhood around the cut-off show a significant difference in the probability of receiving the treatment. The probability of treatment assignment jumps by nearly 20 percentage points for districts just below the literacy cut-off.

The validity of RD design requires that there is no manipulation of the assignment variable around the cutoff. The DPEP program was introduced for the first time in the year 1994. As the eligibility criteria for DPEP funding was based on a predetermined variable (female literacy rate as per 1991 census) individuals do not have precise control to select themselves into the program. We further provide a formal test to check whether the density of the assignment variable is continuous or not around the cut-off. In figure 5, we can see that there is no discontinuity in the assignment variable. Further, to the best of our knowledge no other government program used female literacy rate for program eligibility.

Finally, we provide balance test on predetermined variables that would otherwise bias the estimated parameters (table 3). We use the district level data of DHS 1991-92 to estimate the difference in the pre-determined variables using the RDD method discussed above. The RDD coefficients are not significantly different from zero.

5 Results

Our main results examine the effect of education on women's age at marriage and other marriage market and fertility outcomes. Table 4 reports the estimate for increase in women's education using non parametric inference procedure as shown in equation 2. In the table we show the impact of the program using different bandwidth specification such as mean square error (MSE), coverage error rate (CER) and using different bandwidth on both sides of the cut-off (MSE-2 and CER-2). We find that the program lead to an increase in women's education of around 0.8 to 1.48 years. The MSE optimal bandwidth estimate shows that on average women in the treated district completed 1.48 more years of education. CER-2 have an impact of 0.8 more years of education. Our estimates are comparable to Sunder (2020) who also find that the program increased women's education by around 0.8 years. Another study by Akresh, Halim, and Kleemans (2018) on the long term effect of school construction program in Indonesia, report an average effect of 0.46 years of education for women in treated district. One of the reasons for the large effect in our study could be because we are estimating a local average treatment effect (LATE) for those districts around the cut-off who were induced into taking the program as opposed to average treatment affect.

The main question of the paper is to estimate the impact on age at marriage due to increase in education. To check if the age at marriage is falling due to increase in woman's education, we use the 2SLS approach as shown in section 4. We present the reduced form estimates using 2SLS in table 5. In the first stage we use DPEP cut-off indicator as an instrument for education around the female literacy cut-off. We use bandwidth from previous RDD specification where we estimate the impact of DPEP program on education (section 4). It is estimated using MSE-optimal bandwidth framework i.e 4.7. It is used in all IV specification.

Table 5 shows the second stage results of the impact of education on age at marriage using the IV estimation. The IV estimates show that an increase in education is associated with a fall in the age at marriage by nearly 5 months. The results suggest that on average educated women in the treated districts are married just after reaching legal age of marriage, 18. We do not find any impact on the age at which women give birth to their first child. The fertility outcomes show that the educated women are more likely to have fewer children than the less educated women. Further, we strengthen our results using various robustness checks which are discussed in the section 9.

6 Impact of education on marriage surplus

At equilibrium, a stable match is formed when there is an increase in the individual's utility from the match or if they do not find a better match than the current one. Hence, we check if there is increase in the surplus within marriage for the educated woman. An increase in education should be followed with an increase in the surplus, if education of women is a preferred attribute on the marriage market. We use a similar IV framework as discussed in the section 4 to identify the impact of women's education on their post marriage well being indicators. We focus on three important indicators - experience of domestic violence their health status post marriage and their decision making power.

6.1 Domestic violence

The stability of marriage is usually measured by the divorce rates. In India, since the divorce rates are very low. Hence, it does not provide a good measure of stability of the match. Instead, we use domestic violence post marriage as an indicator of conflict or an unstable match. We use two variables to measure the extent of domestic violence. First, *Any Violence*, is the ratio of women who reported in the survey that they faced any form of physical, sexual, emotional violence or control behaviour by partner. It can be used as a direct measure of the conflict within marriage. We find that the probability of *Any Violence* decreases due to increase in education. As shown in table 8, the drop in *Any Violence* is around 22 percent and significant. The control mean of 0.27 shows the impact of education on *Any Violence* is substantial.[2] Second, *Justifies Violence* records if the woman justifies violence under any circumstance i.e. if the wife thinks that her husband can beat her if she was unfaithful, disrespectful or in any other circumstance. The negative coefficient in this specification suggests that due to education fewer women justify violence within marriage. The reduction both in the experience and justification of domestic violence indicates that with increase in education a more stable match is achieved.

6.2 Wealth and Health

We use other measures to test whether more educated woman benefit from the match. We check if women marry in a wealthier household or avail health care benefits post marriage. In this section, we check the impact of increase in education on wealth and health care access.

First, *Household wealth* is used as an indicator of husband's wealth percentile category. We create a binary variable indicating if the household is above or below median on the wealth distribution. Using our IV specification (as in section 4), we find that the educated woman in the treated districts are more likely to get married in wealthy households as compared to uneducated women (see column 1 table 9). This indicates assortative matching on women's education and men's wealth.

Second, health care access is measured using hospital delivery, antenatal care and use of contraception. We present these results in columns 2-4 of table 9 .We find there is 7 percent increase in the hospital delivery post marriage due to education. There is 5 percent increase in the antenatal care access for educated women post marriage. The use of contraception also increases by 14 percent for the educated women. These measures indicate improved health care access for the women post marriage.

[2]In DHS, a random sub-sample was used for the domestic violence module

6.3 Decision making power

Lastly, we also check if there is any change in the decision making power of the women post marriage. Given there is less autonomy for women in the decision making (Misra, 2006). A stable match would expect an increase in the decision making power for the educated women.

We use following purchasing decision making indicators, person who decides on spending the women's own earning, person who decides on the women's healthcare spending, and person who decides on major household purchases. We create a binary variable with value one if the women is involved in the decision making else zero as shown in table 10. Using the similar IV specification (as in section 4), we find education does not change the decision making power for the women significantly in own earnings, household purchases and health care spending. Most of the indicators show the stability of the match post marriage for the educated women.

7 Theoretical Framework

The economic analysis of marriage market is usually analyzed using either frictionless matching framework or search models. In search model, frictions are important. It involves search cost and discounting the risk of never finding a partner. Matching models assumes frictionless environment. It assumes each woman has access to pool of all potential men with perfect knowledge of the characteristics of each of them. In the context of India, marriage migration for the women is the norm. Usually, women leaves her place of origin to join her husband's family. However, 73% of the women stay within their birth district after marriage (Beauchamp, Calvi, & Fulford, 2017). These marriages are predominantly within same caste community. Chiplunkar and Weaver (2021) report that 94% of the marriages occur within same caste or jati. The links within the community are very strong. So there will be full information available to the family about the match especially within a district. Given the low marriage migration outside the district and full information available about the match, the use of frictionless matching framework is appropriate for our setting (Chiappori, 2020; Chiappori, Dias, & Meghir, 2018; Low, 2014).

In this paper, we use an ad-hoc model that creates a conceptual framework to understand our empirical findings on age at marriage. We use a transferable utility (TU) framework in a unitary household model.[3] For women, we have two dimensions: education (H_w) and age (a_w). For men, we have one dimension, income (y). Men prefer to marry younger women due to longer fertility cycle, lesser autonomy and perceived high quality. Also, education of women is a desirable attribute in the marriage market due to the inter-generational transmission of health and education. For women's parents, daughter's education increases the chances of her securing a better match.

Individuals care about children (Q) and private consumption (q). The post-marriage surplus, $s(y, H_w, a_w)$, produced from the consumption can be estimated by maximising the sum of utilities of men and women. Let the surplus exhibit following properties:

1. Supermodularity in income and education: $\frac{\partial s^2}{\partial y \partial H_w} > 0$
2. Women's preference for high income: $\frac{\partial s}{\partial y} > 0$
3. Men's preference for educated brides: $\frac{\partial s}{\partial H_w} > 0$
4. Men's preference for younger brides: $\frac{\partial s}{\partial a_w} < 0$

The household surplus is supermodular in income and women's education. Given the preferences, the surplus is increasing in education of women and decreasing in the age of women. This will create a negative association between the two traits in the matching function. To see this trade-off mathematically, we derive the marginal rate of substitution between these two traits along the surplus function. In the appendix, we show the surplus

[3] In a unitary household model one maximises the total surplus of the household and not the share within the household

maximisation and marginal rate of substitution for a specific functional form.

$$MRS = \frac{\frac{\partial s}{\partial H_w}}{\frac{\partial s}{\partial a_w}} = \frac{\partial a_w}{\partial H_w} < 0$$

8 Labour market returns and age at marriage

Education for women is valued in the marriage market and labour market. The outside option for the women can play a significant role in the decision of marriage. In the paper, we find that the educated women has lower age at marriage as compared to uneducated women. But this may change if the educated women has a better outside option. Here, we investigate the impact of increase in the labour market returns on the age at marriage for the educated women.

The labour market returns can be measured by women's wage levels in the district, an intensive margin measure, and female labour force participation at the district level, an extensive margin measure. The wage variable is constructed using National Sample Survey (2005) weekly wage variable for women. Using the same database we create female labour force participation at the district level.

Here, the objective is to understand the impact of education due to an increase in the wage level on the age at marriage. We use similar IV specification as discussed in the section 4, where DPEP is used as an instrument for education. To measure the impact we interact the DPEP variable with wage level. In table 13, see a positive coefficient for the interaction between education and district level women's wage. It implies there is delay in the age at marriage by 0.1 years as the weekly wage increases by 100 INR for the women i.e. equivalent to 25 percent of the average weekly wage. The outside option for the women plays an important role in the decision of the marriage. With increase in the labour market returns there can be delay in the age of marriage.

9 Robustness checks

The DPEP cut-off provides with a good instrument to estimate the impact of education on age at marriage. Although, the identifying assumption is valid only in the close neighbourhood of the cut-off. Thus, it is important to see how sensitive the estimates are to choice of bandwidths. In all our IV specifications, we use the bandwidth from the first stage of RDD regression (equation 1). We follow the method for optimal bandwidth selection using mean square error as in Calonico et al. (2017). This gives us a bandwidth of 4.7. We check the impact on age at marriage for different bandwidth sizes. In table 5, we show the impact for bandwidth 4, 6 and 7 percent. We find that the impact on age at marriage is still negative and significant.

The target group of the DPEP program consists of individuals, below the age of 19 in 1994. In 2015, this corresponds to women below the age of 40. Thus, for our analysis we focus on women in the 15-40 age group in the year 2015. This provides us with a sample of 543,023 eligible women. Out of these, 358,303 women are married in the sample (69 percent). In our sample there can be some individuals who have not yet finished their marriage cycle. For instance, an individual who is 21 years old now could get married at age of 23, but is accounted for as we are only looking at those who are currently married. This leads to censoring bias in the sample. We might underestimate the average age at marriage by censoring individuals who marry later. To deal with this we create another sample where we look at women in the age group 25-40. Since most women in our sample get married by the age of 25, we can say more confidently that the age group 25-40 includes individuals who have completed their marriage cycle.[4] Table 6 compares the impact on age at marriage for various age-group samples. Column 2 shows the impact of age group 25-40. The age at marriage decreases by around 1 year due to increase in education. As expected, the fall in age at marriage is smaller for this age group as it accounts for the negative censoring bias by looking only at those who have completed their marriage cycle.

[4] 96 percent in the sample get married by the age of 25.

The DPEP program lead to an increase in education for both men and women. This makes it difficult to disentangle the effect on increase in women's from increase in men's education on age at marriage. To understand more clearly the mechanisms for the fall in age at marriage for women we carry out two separate analysis. First, we check the impact of increase in education on husband's age at marriage. DHS has information on husband's characteristics. This sample survey was conducted on randomly drawn men from the full women sample. Using similar IV specification, we find that there is no impact of education on husband's age at marriage as shown in table 11. This implies that due to increase in education only women's age at marriage has changed and not men's. Next, we also check the impact for a specific cohort where only women were exposed to the program and men were not exposed to the program. This would suggest during the implementation of program men were too old to change their decision and women were exposed to the program. On average there is 4-5 years difference in age of husband and wife, so this sample is similar to the full sample. Column 4 in table **??** shows the impact on this specific cohort. The impact on age at marriage is negative. Due to small sample size we lose significance of our estimate.

An increase in the women's education can have heterogeneous impact on age at marriage depending on the level of education attained. Here, we check for the distributional impact on age at marriage at different quantiles of education attained. We perform IV quantile regression to study the distributional impact of education on age at marriage using the framework of Kaplan and Sun (2017). Table 12 shows the impact of depending the level of women's education.[5] We find that the there is fall in age at marriage for mean and median level of education (8 years). At higher education quantiles there is further decrease in age at marriage. Hence, we find the fall in age at marriage is not just around the mean but it is also prominent along the distribution.

Next, we estimate the model with difference-in-difference strategy. This estimation would allow us to capture the intention to treat effect. Districts received the program at different

[5]The education quantiles follow the categorisation as mentioned: Q25 has 5 years of education; Q50 has 8 years of education; Q75 has 14 years of education.

years between 1994 to 2002. For each of the treatment years, we compare districts that received DPEP to districts that did not receive DPEP. The treated cohort is women who were 9-19 years of age when DPEP was implemented in their districts and the control cohort is women who were too old to change their schooling decisions, hence, ages 20-30.

$$Y_{id} = \beta_0 + \beta_1 Cohort_i + \sum_{t=1994}^{2002} \beta_t DPEP_{td} + \sum_{j=1994}^{2002} \beta_j Cohort_i \times DPEP_{jd} + \alpha_d + \epsilon_{id} \qquad (5)$$

From figure 6, we find that for every year of DPEP implementation, the age at marriage in DPEP districts decreases significantly for the treated cohort of women.

10 Conclusion

In this paper we study the relationship between women's education and the age at marriage. We estimate this by exploiting the quasi-random variation created by a large scale education intervention called DPEP that targeted districts with low female education.

Our empirical findings show that with an increase in female education due to DPEP, the age at marriage decreased by 0.44 years or by 5 months. This implies that the in the treated districts women who completed primary schooling are more likely to be married just after reaching legal age. These women are have fewer children than women who do not complete primary school. Our results indicate that surplus obtained from marriage for educated women is higher than uneducated women when labour market prospects are scarce. However, we also see that as women's labour market returns increase, they delay marriage. Contrary to existing evidence that shows a positive relation between female education and delay in marriage, our findings have important implications for policy. In countries where women traditionally have early marriages and do not work outside home, education would lead to a delay in marriage when labour market opportunities for women increase. It highlights the importance of complementarity of policies to achieve the policy goal of delay in women's age at marriage. Education as a policy tool needs to be combined with other policy that will provide better economic opportunities to women to delay the age at marriage.

11 FIGURES

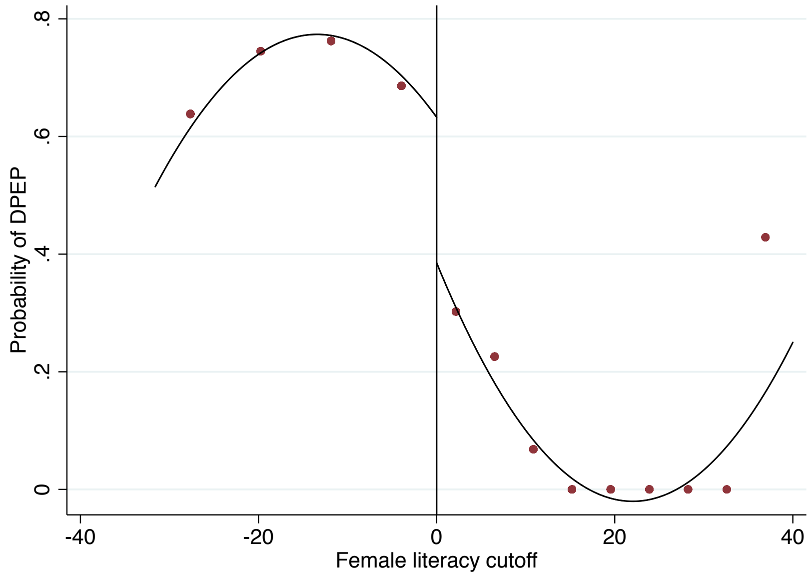

Figure 1 Probability of receiving DPEP
Figure Notes: This figure plots the discontinuity in the probability of receiving DPEP for districts around the female literacy cutoff. The districts to the left of zero receive the program and the districts to the right do not.

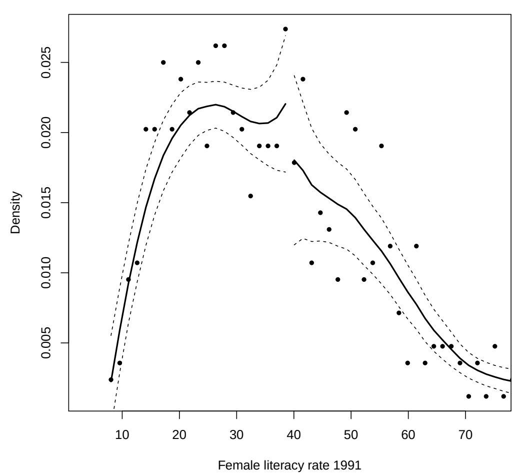

Figure 2 Mccrary Test
Figure Notes: This figure plots the continuous density of the assignment variable around the cutoff.

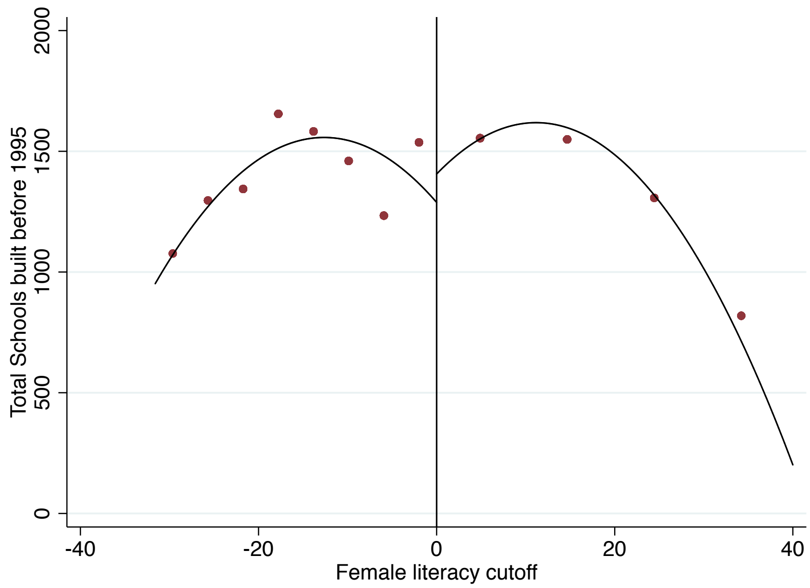

Figure 3 Balance test: Schools built before 1995
Figure Notes: This figure plots the continuity in the district wise total schools before 1995 around the female literacy cutoff. The districts to the left of zero receive the program and the districts to the right do not.

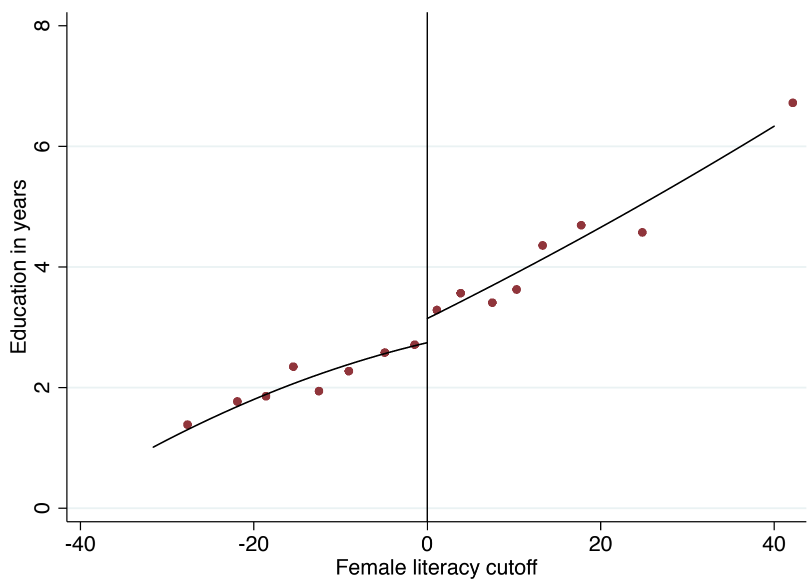

Figure 4 Balance test: Education
Figure Notes: This figure plots the continuity in the district wise female years of education around the female literacy cutoff. The districts to the left of zero receive the program and the districts to the right do not.

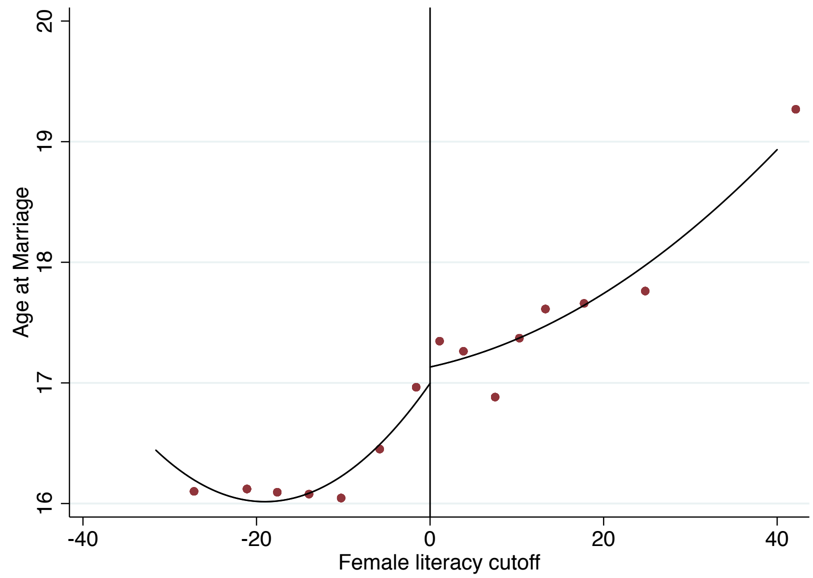

Figure 5 Balance test: Age at marriage
Figure Notes: This figure plots the continuity in the district wise women's age at marriage around the female literacy cutoff. The districts to the left of zero receive the program and the districts to the right do not.

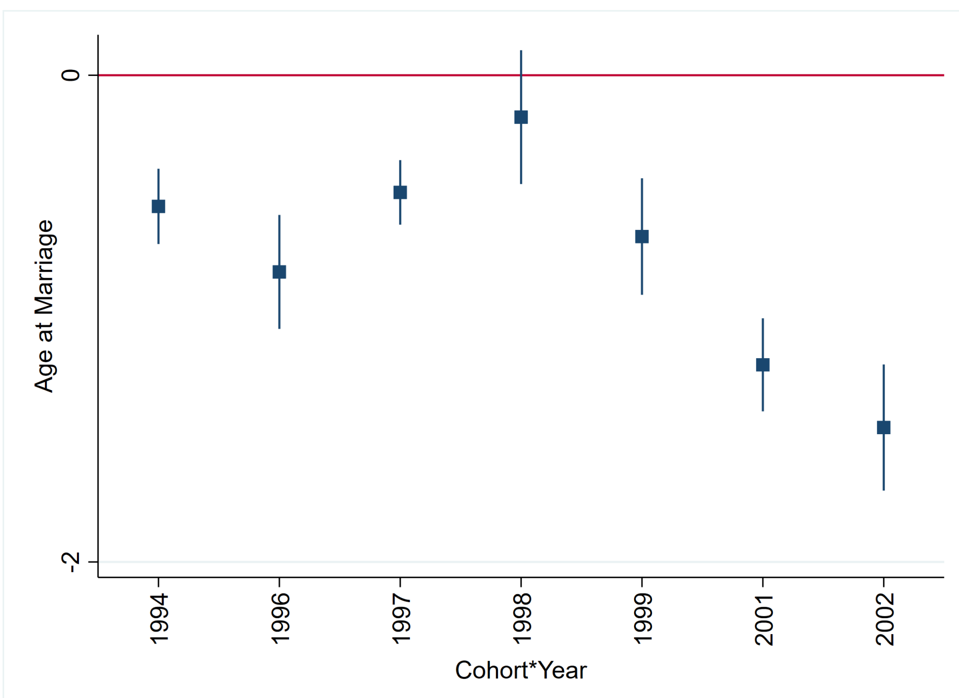

Figure 6 Difference in Difference
Figure Notes: This figure plots the staggered difference in difference estimates for treatment years 1994 to 2002. The treated cohort is women who were 6-19 years of age and the control is women who were 20-30 at the time of program implementation. We include cohort, DPEP and district level fixed effect.

11 TABLES

Table 1 Descriptive statistics

	N	Mean	SD	Min	Max
DHS, 2015-16					
Marriage and fertility					
Age at marriage	358,303	18.65	3.73	10	40
Age at first birth	316,728	20.63	3.41	15	40
Total children	543,023	1.46	1.56	0	15
Background variables					
Woman age	543,023	26.03	7.14	15	40
Education in years	543,023	7.49	5.01	0	20
HH. size	543,023	5.94	2.69	1	41
Ever married	543,023	0.69	0.46	0	1
Ever gave birth	543,023	0.60	0.49	0	1
Partner Age	63,040	33.77	7.28	15	70
Partner Education	65,241	8.00	4.86	0	20
Partner Age at marriage	62,576	23.37	4.75	10	40
Surplus variables					
Own earning decision	13,289	0.82	0.39	0	1
Health decision	543,023	0.09	0.28	0	1
Purchase decision	543,023	0.08	0.28	0	1
Faced any violence	48,623	0.32	0.46	0	1
Justifies violence	93,289	0.39	0.49	0	1
HH. Wealth	543,023	0.38	0.49	0	1
Hospital deliveries	181,160	0.78	0.41	0	1
Antenatal care received	179,729	0.83	0.38	0	1
Use contraception	381,378	0.56	0.50	0	1
NSSO, 2005					
Median District wage (Women)	488,379	414.30	445.45	90.00	3,000.00
Median District LFPR (Women)	493,474	0.36	0.16	0.00	0.79
Marriage squeeze	493,474	140.78	72.61	24.32	700.00
DISE, 2005					
Schools built before 1995	511,582	1,343.87	819.25	16	5,196
Census, 1991					
DPEP	543,023	0.40	0.49	0	1
Female lit. rate 1991 (centered)	467,687	−3.12	17.07	−31.60	54.70
Sex ratio 1991	377,404	943.64	34.09	851.94	1,079.71
States	36				
Districts	632				
Observations	543,023				

Notes: Summary statistics for four datasets combined. DHS (2015-16): Sample from woman questionnaire for all those who were young in 1994-2005, DISE (2005): District level school indicators, Census of India (1991): District level Primary census abstracts. NSSO (2005), Employment Unemployment Survey. The combined data consists of total 543,023 observations and 632 districts (including splits) out of which 267 got DPEP and remaining did not.

Table 2 Description of variables

DHS, 2015-16	
Marriage market variables	
Age at marriage	Age at start of first marriage or union.
Age at first birth	Age of the respondent at first birth.
Total children	Total number of children ever born.
Background variables	
Woman age	The present age of the woman.
Education in years	Education in single years.
HH. size	Total members of the household.
Ever married	Dummy for woman who ever got married.
Ever gave birth	Dummy for woman who ever gave birth.
Partner Age	Age of the respondent's husband or partner.
Partner Education	The current husband or partner's education in single years.
Partner Age at marriage	The age at marriage of the current husband.
Surplus variables	
Own earning decision	Person who decides how to spend the woman's own earnings
Health decision	Person who decides on the respondent's health care
Purchase decision	Person who usually decides on large household purchases
Faced any violence	If the woman faced physical, sexual, emotional violence or control behaviour by partner.
Justifies violence	If the woman justifies physical, sexual, emotional violence or control behaviour under any circumstances.
HH. Wealth	Wealth category post marriage
Hospital deliveries	Delivery in a health institution
Antenatal care received	Access to antenatal care during pregnancy
Use contraception	Access to any type of contraceptive methods
NSSO, 2005	
Median District wage (Women)	The median of individuals weekly wages at district level.
Mean District LFPR (Women)	The average LFPR at district level using the current weekly activity status.(Total women age 15-65 working or looking for work/Total women age 15-65)
Marriage squeeze	Ratio of unmarried women age 15-19 to unmarried men age 20-24.
DISE, 2005	
Schools built before 1995	Total schools built before the year 1995.
Census, 1991	
DPEP	Dummy for whether the district got DPEP funding or not.
Female lit. rate 1991 (centered)	District level average female literacy minus the national average female literacy rate (39.3).
Sex ratio 1991	Total number of females per thousand males.

Notes:

Table 3 Balance test covariates

	(1) Education	(2) Age at marriage	(3) Schools built	(4) Sex ratio	(5) Total children
DPEP	-1.471	-1.254	720.203	9.333	-0.113
	[1.526]	[1.396]	[445.564]	[39.820]	[0.387]
Sample Mean	3.04	16.90	584.68	942.58	2.64
BW districts	209	135	117	174	189
Bandwidth	14	10	8	12	12
VCE method	NN	NN	NN	NN	NN
BW type	mserd	mserd	mserd	mserd	mserd

Notes: The balance test checks the difference between DPEP and non-DPEP districts before the program was implemented. We use fuzzy RDD design to estimate the impact on the predetermined variables (Calonico et al., 2017). The bandwidth selection is done using data driven mean square error (MSE-RD) optimal bandwidth methodology. The estimation is done at district level. We use nearest neighbour (NN) cluster robust standard errors at district-age level.
$^{**}p<0.05$;$^{***}p<0.01$

Table 4 Impact of District Primary Education Program (DPEP) on women's education

	(1) MSE	(2) MSE-2	(3) CER	(4) CER-2
DPEP	1.48**	0.33	0.40	0.83*
	[0.72]	[0.35]	[0.81]	[0.46]
Sample Mean	7.49	7.49	7.49	7.49
Obs.	467687	467687	467687	467687
BW-left	4.71	3.06	2.93	1.90
BW-right	4.71	7.71	2.93	4.79
BW type	mserd	msetwo	cerrd	certwo

Notes: Here we estimate the impact of the DPEP program on women's education using non-parametric estimation using different optimal bandwidth selection methods such as MSE, MSE-2, MSE-sum, CER, CER-2 and CER-sum. MSE represents Mean Square Error; MSE-2 represents different bandwidths for both sides of the cut-off; CER represents Coverage Error Rate. We use NN cluster robust standard errors at district age level. $^{**}p<0.05$;$^{***}p<0.01$

Table 5 Impact of education on age at marriage

		Old Cohort	Bandwidth		
	Main	26-40	4	6	7
Educ.	-0.44***	-1.06**	-1.17***	-0.76***	-0.48***
	[0.17]	[0.41]	[0.40]	[0.28]	[0.16]
Obs.	58140	39385	51364	72784	83379
Control Mean	18.78	19.07	18.76	18.77	18.67
CD Fstat	37.63	14.43	16.52	20.84	43.69

Notes: Here we show results for robustness checks on the impact of education on age at marriage. In column 2 we use old cohort in the age group of 25-40. In the last three columns we use different bandwidth specification. **p<0.05;***p<0.01

Table 6 Impact of education on age at marriage: Age Cohort

	Main	15-25	26-40	27-35
Education	-0.44***	0.26**	-1.06**	-0.60*
	[0.17]	[0.10]	[0.41]	[0.33]
Observations	58140	18755	39385	26699
Control Mean	18.78	18.17	19.07	19.07
CD Fstat	37.63	30.44	14.43	12.96

Notes: Here we show results for robustness checks on the impact of education on age at marriage. In column 2 and 3 we use old cohort in the age group of 25-40 and 30-40 respectively. In column 4 we use cohort where only women were treated in the program and men were too old to change their schooling decision. **p<0.05;***p<0.01

Table 7 Impact of education on marriage market outcomes

	(1) Age at First Birth	(2) Total Child
Education	-0.22	-0.06**
	[0.16]	[0.03]
Observations	51502	87991
Control Mean	20.63	1.46
CD Fstat	26.04	97.05

Notes Here we show the robust estimate for the impact of education on marriage market outcomes. We use DPEP cut-off as an instrumental variable for education. We use the first stage bandwidth of 4.7 around the cut-off. This includes 54 districts below the cut-off and 44 districts above the cut-off. We use nearest neighbour (NN) cluster robust standard errors at district age level. **p<0.05;***p<0.01

Table 8 Impact of education on domestic violence

	(1) Any Violence	(2) Justifies Violence
Education	-0.22***	-0.14***
	[0.08]	[0.03]
Observations	7688	14485
Control Mean	0.27	0.38
CD Fstat	7.57	33.38

Notes This table shows the IV estimates for the impact of education on domestic violence variables. The first column records if the woman has experienced any sort of physical, sexual violence or has faced control issues. The second column records if the woman justifies violence if the wife was unfaithful or disrespectful. The variable *Fem. Lit.* is the districtwise female literacy in 1991. **p<0.05;***p<0.01

Table 9 Impact of education on wealth and healthcare access

	(1) Household Wealth	(2) Hospital Delivery	(3) Antenatal care	(4) Contraception
Education	0.15***	0.07***	0.05***	0.14***
	[0.01]	[0.01]	[0.01]	[0.03]
Observations	87991	28210	27897	61702
Control Mean	0.48	0.82	0.87	0.57
CD Fstat	97.05	65.09	63.93	35.45

Notes This table shows the IV estimates for the impact of education on wealth and health related variables. The reference for column 1 is individuals belonging to the DHS wealth categories - middle, poorer and poorest. The reference for columns 2 - 4 is no access to that particular healthcare facility. The variable *Fem. Lit.* is the districtwise female literacy in 1991. **p<0.05;***p<0.01

Table 10 Impact of education on spending decisions within household

	(1) Own Earnings	(2) Health care	(3) Purchases
Education	-0.19	-0.01*	-0.01
	[0.56]	[0.01]	[0.01]
Observations	2358	87991	87991
Control Mean	0.85	0.09	0.09
CD Fstat	0.14	97.05	97.05

Notes: This table shows the IV estimates for the impact of education on decision making within household. The dependent variables in columns 1 to 3 are *person who decides on spending the woman's own earning, person who decides on the woman's healthcare, person who decides on major household purchases* respectively. The reference for all columns is that the husband or someone else in the household takes decisions vs the woman taking the decisions alone or jointly with the husband. The variable *Fem. Lit.* is the districtwise female literacy in 1991. **p<0.05;***p<0.01

Table 11 Impact of education on husband's characteristics

	(1) Husband's AM	(2) Husband's Education
Men's Education	0.27	–
	[0.32]	
Women's Education	–	0.07*
		[0.04]
Obs.	9729	10224
Control Mean	23.37	18.78
CD Fstat	8.98	17.43

Notes: Here we estimate the impact of education on husband's age at marriage. This data is randomly selected sample from the women questionnaire. Hence, there are lower number of observations in the analysis. The second column estiamtes the difference in age at marriage between husband and wife due to increase in wife's education. The column 3 estimates impact of increase in men's education on difference in age at marriage. **p<0.05;***p<0.01

Table 12 Impact of education on marriage market outcomes

	(1) Q25	(2) Q50	(3) Q75	(4) Q90
Education	0.26***	-0.08***	-0.24***	-0.49***
	[0.05]	[0.03]	[0.03]	[0.08]
Observations	309607	309607	309607	309607

Notes: Here we estimate the distributional impact of the education on age at marriage using IV quantile treatment effect at different levels of education using Kaplan and Sun (2017) methodology. The education quantiles follow the categorisation as mentioned: Q25 has 5 years of education; Q50 has 8 years of education; Q75 has 14 years of education. **p<0.05;***p<0.01

Table 13 Impact of education on age of marriage: wage levels

	(1) Wage
Education	-0.7872**
	[0.4011]
Education × Wage	0.0009***
	[0.0003]
Wage	-0.0056**
	[0.0022]
Observations	57648
Control Mean	19.51
CD Fstat	7.00

Notes Here we estimate the heterogeneity depending on outside option available in terms of district wage for women. Wage means district level wage of women. We use similar IV specification with DPEP cut-off as an instrument for education. The CD Fstat 7 is significant at 10 percent level. With two instruments Craig Donald Fstat is a better statistics to check the validity of the instrument. Stock Yogo (SY) provides the critical values. For this specification the SY critical value is 7 at 10 percent level. **p<0.05;***p<0.01

A Conceptual framework: household problem

The utility for men and women is represented by subscript m and w respectively. Individuals value the private consumption, q, and children and household management as a public good, Q. The household production function follows Cobb-Douglas utility (qQ). The men's family has a preference for young brides. We add cost in the utility function which increases with age of the woman at marriage. $c(a_w)$ is an increasing function of age. Below is the utility for men and women both:

$$u_m = q_m Q - c(a_w)$$

$$u_w = q_w Q$$

We assume the investment in children depends on the parental human capital. The public good, Q, domestically produced from parental human capital is given by Cobb-Douglas utility function.

$$Q = H_m^{\alpha/2} H_w^{\alpha/2}$$

The budget constraint of the household will account for private consumption q and public good consumption i.e. child care. The sum of the consumptions will be equal to household income. We have husband's income, y, bride's income, z, and dowry payment, d. Dowry payment is one time usually around annual income of the husband. But we can consider it as small monthly payment over the life-cycle. Below is the budget constraint for the household. Here we assume the share of private consumption and public consumption is defined by β.

$$q_m + q_w + \beta Q = y + d + z$$

Dowry is an important part of Indian marriage market. It can exceed annual household income (Chiplunkar & Weaver, 2021). We introduce dowry in the model through budget constraint as an perpetuity monthly payment. For simplification, we assume dowry to be a constant amount.

In India, female labour force participation has stagnated around 30 percent and it has decreased in recent years. So the main investment is in the marriage market (Fletcher, Pande, & Moore, 2017). Labour market returns are low for woman but they do increase with education. We assume similar logarithmic functional form for women's income. The labour market returns can be assumed to be low which means a low value of δ or z'_{H_w}.

$$z = \delta ln(H_w)$$

Here, we maximise the total household utility under the budget constraint. More specifically, we maximise the sum of utilities for men and women in the household, $u = u_m + u_w$. Below is the maximisation problem:

$$\max_{q,Q}.\ (q_m + q_w)(Q) - c(a_w)$$

$$s.t.\ q_m + q_w + \beta Q = y + d + z$$

We get equilibrium private consumptions and public good consumption. The equilibrium values for private and public good consumption are:

$$Q^* = \frac{(y + z + d + R)}{\beta + 1}$$
$$q^* = \frac{(y + z + d - R)}{\beta + 1}$$

where $R = \frac{2\delta}{\alpha}$.

A.1 Surplus function

From the optimal values we can get the joint utility for the household. Joint utility of the household, T, is the sum of utilities of men and woman as shown below:

$$T = q^* Q^* - c(a_w)$$
$$T = \frac{1}{(\beta + 1)^2}((y + z + d)^2 - R^2) - c(a_w)$$

Using joint utility we can define the surplus of the household. Surplus function is defined as joint utility minus the utility when the individuals are single. When they are single consume their own income. Using optimal values for private and public good consumption we get surplus function:

$$S(y, z, H_w, a_w) = \frac{1}{(\beta + 1)^2}((y + z + d)^2 - R^2) - c(a_w) - y - z$$

The surplus function depends on labour market income for men and women. It reduces with age of woman at marriage. As men's family prefer younger brides surplus decreasing in the age of woman. We also have surplus increasing in men's income.

A.2 Marginal rate of substitution

Using the surplus function, we estimate the rate of change of surplus with respect to age at marriage and education of the woman. Further, we comment on the marginal rate of substitution between age of marriage and education of the woman.

$$\frac{\partial S}{\partial H_w} = (\frac{2(y+z+d)}{(\beta+1)^2} - 1)z'_{H_w}$$

Given that we have the numerator positive we have surplus increasing in education of women. For that we need $2(y+z+d) > (\beta+1)^2$.

$$\frac{\partial S}{\partial H_w} > 0$$

Next, we estimate the rate of change of surplus with respect to age of marriage. Surplus of the household decreases as the age of woman increases.

$$\frac{\partial S}{\partial a_w} = -c'(a_w)$$

Further, we estimate the marginal rate of substitution ($MRS_{a_{H_w}}$) between age of marriage and education of woman. We estimate the MRS by taking a ratio between marginal surplus of education of woman and age of woman at marriage. If the labour market returns are low for woman then we get the MRS to be negative. The model predicts a negative association between education of woman and the age of marriage. There is demand for young and educated brides. Educated woman are able to find a match earlier after entering the marriage market.

$$MRS = \frac{\partial a_w}{\partial H_w} < 0$$

A.3 Household problem: quasi-linear utility

Here, we use similar set-up as the earlier problem. We use quasi-linear utility functional form where the private consumption does not depend on change in household income. We assume following functional forms:

$$u_m = q_m + ln(Q) - c(a_w)$$
$$u_w = q_w + ln(Q)$$

Another deviation from the above model is we assume dowry increases with education of women. There is evidence of positive correlation between dowry and education of woman (Anukriti, Kwon, & Prakash, 2020). We assume dowry is an increasing function of education of woman. We take a specific logarithmic functional form in our specification. Dowry, d, depends on the woman's human capital, H_w, as shown below:

$$d = \gamma ln(H_w)$$

Keeping rest of the assumption similar to above household problem, we maximise the sum of utilities under the budget constraint. We get following equilibrium values:

$$Q^* = 2\frac{\alpha + \delta}{\alpha\beta}$$
$$q^* = (y + z + d) - 2\frac{\alpha + \delta}{\alpha\beta}$$

This provides us with the following surplus function which is independent of the income (y and

z).

$$S(H_w, a_w) = \gamma ln(H_w) - 2\frac{\alpha + \delta}{\alpha\beta} + ln(2\frac{\alpha + \delta}{\alpha\beta}) - c(a_w)$$

The marginal rate of substitution between education of women and age of marriage has a negative relationship using this functional form as well.

$$\frac{\partial S}{\partial H_w} = \frac{\gamma}{H_w}$$
$$\frac{\partial S}{\partial a_w} = -c'(a_w)$$
$$MRS = -\frac{\gamma}{H_w c'(a_w)}$$

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