Testing the Role of Unobserved Endowments in Marriage Matching Models: A Method Based on MZ-DZ Twin Experiment

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Abstract

Marriage matching is determined by both observed and unobserved individual attributes. The recent literature on estimating marriage matching models imposes strong assumptions on the relationship between unobserved and observed attributes. This paper investigates such assumptions and examines how earnings-related endowments, which are unobserved by researchers, differentially affect marital outcomes between men and women. We build a novel econometric model to perform the identification by exploiting the monozygotic (MZ)-dizygotic (DZ) twin experiment. Within-twin-pair difference in unobserved endowments is smaller for MZ twins than for DZ twins, because MZ twins are genetically identical at conception and DZ twins are not. Using data from the Chinese Adult Twin Survey, we find that conditional on education, better endowed male twins, compared with their lower endowed twins, tend to marry earlier; by contrast, better endowed female twins tend to marry later. We further find that better endowed male twins tend to marry younger and taller wives, while better endowed female twins tend to marry higher educated and better paid husbands. Our findings suggest that unobserved earnings endowments significantly correlate with observed attributes during the matching process, and that the correlations are gender asymmetric.

Keywords: Assortative marriage matching; unobservable attributes; observed attributes; earnings-related endowments; MZ-DZ experiment

JEL Codes: C20, J12, J16

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1 Introduction

Assortative marriage matching has important implications for the distribution of household incomes, marriage stability, fertility, and child human capital (Becker, 1973, 1991; Chiappori et al., 2017; Weiss, 1997). Since the seminal work of Becker (1973), a large literature has theoretically and empirically studied marriage matching. Early studies applied and tested implications derived from marriage matching models (Grossbard-Shechtman, 1993; Lam, 1988; Zhang and Liu, 2003). Choo and Siow (2006) pioneered a new generation of studies to parametrically or nonparametrically estimate marriage matching models (Chiappori et al., 2012, 2017; Choo, 2015; Dupuy and Galichon, 2014; Fox et al., 2018; Galichon et al., 2019; Galichon and Salanié, 2015, 2017; Hitsch et al., 2010; Siow, 2015). These papers estimate equilibrium marriage payoffs and mate preference parameters in marriage matching models using data on who marries whom and the observed attributes of individuals, while imposing strong assumptions on the distribution of unobserved individual attributes and on the relationship between unobserved and observed attributes.

The main assumption regarding unobserved attributes is separability: Match-specific unobservable error is additively separable for observable attributes in the marital payoff function. This assumption implies independence between unobserved attributes and observed attributes. For analytical tractability, Choo and Siow (2006) initially assume that unobserved heterogeneity is a logit error term, which enters the marital surplus quasi-additively and is distributed as a standard type I extreme value term.[1] This assumption has often been invoked in later studies (Choo, 2015; Hitsch et al., 2010; Siow, 2015).[2] Unlike Choo and Siow (2006), who estimate marital surplus for the matching pattern by restricting the distribution of unobserved heterogeneity,

1. Unobserved heterogeneities could come from various sources, such as endowments, attributes, preference, household productivity, and matching frictions. We focus on unobserved endowments or attributes in this paper.

2. Dupuy and Galichon (2014) extend Choo and Siow's (2006) matching model to the continuous case. Galichon and Salanié (2015, 2017) and many other works by Galichon and coauthors (Ciscato et al., 2020; Dupuy et al., 2020) relax the distributional assumption of unobserved heterogeneity and extend the original model of Choo and Siow (2006) to a rich set of contexts.

Fox et al. (2018) develop a different approach to estimate the matching model: Restrict the mean surplus and identify the distribution of unobserved heterogeneity from matching patterns across multiple marriage markets. Despite using a different approach, Fox et al. (2018) invoke the same assumption of independence between observed and unobserved attributes as Choo and Siow (2006). In addition, Chiappori et al. (2012) assume that all observed attributes of either men or women can be summarized by an index, which is used as a proxy for attractiveness. Unobserved attributes are allowed to be correlated with the index of attractiveness; conditional on the index, unobserved attributes are independent from observed attributes.

Because the consistency of estimation procedures for marriage matching models hinges on assumptions on unobservables, it is crucial that we investigate the relationship between observed and unobserved attributes. Though the literature on return to schooling has extensively studied the correlation between unobserved ability and education (Ashenfelter and Krueger, 1994; Li et al., 2012), whether and how unobserved attributes are correlated with observed mate attributes has been less explored in the context of marriage matching. This paper focuses on investigating how earnings-related endowments, which are unobserved by researchers, differentially affect marital outcomes between men and women.[3] By exploiting the monozygotic (MZ)-dizygotic (DZ) twin experiment, we provide robust empirical evidence that strongly suggests that one's unobserved earnings-related endowment significantly and gender-asymmetrically correlates with spousal age, height, education, and wage observed at wedding time. These results cast doubt on the assumption on independence between unobserved and the observed attributes. More appropriate assumptions on unobserved attributes in estimating marriage matching models are required to strike a balance between analytical convenience and reality. To the best of

3. The role of earnings-related endowments in the marriage market has been emphasized theoretically in earlier work (Bergstrom and Bagnoli, 1993; Siow, 1998). Bergstrom and Bagnoli (1993) assume asymmetric information in the marriage market, by which women put more weight on the earnings-related ability of men—which is not easy to observe—whereas men care more about the fecundity of women, which can be observed at a younger age. Consequently, men with higher earnings-related ability tend to marry at an older age, when their economic success is revealed, but there is no benefit for women to marry later. Siow (1998) focuses on the biological fact that women are fecund for a shorter period of their lives than men. His model derives that the differential fecundity between men and women causes age at first marriage for women, on average, to be lower than for men, and leads men with higher earnings-related ability to marry earlier.

our knowledge, this paper is the first to question the separability assumption in the marriage matching model by providing concrete evidence that observed attributes are correlated with unobserved attributes in the marriage matching process.

Unobserved attributes are a crucial issue in estimating marriage matching models, but examining this issue is challenging, because "the econometrician will never be able to know whether two individuals are endowed with the same vectors of unobservables" (Chiappori et al., 2012). To overcome this challenge, we build a novel econometric model by exploiting the MZ-DZ twin experiment. MZ twins are genetically identical at conception, whereas DZ twins differ, so within-twin pair difference in unobserved endowments for MZ twins is smaller than for DZ twins. The critical difference between MZ and DZ twin pairs enables us to design a quasi-natural experiment.

We conduct the empirical analysis in two steps. First, we separately estimate the return to education for MZ and DZ twins. By comparing within-MZ-twin fixed effect (FE) estimates with within-DZ-twin FE estimates of the return to education, we identify the effect of earnings-related endowments on education. Second, we separately regress marital outcomes on education for MZ and DZ twins. Based on (i) the effect of earnings-related endowments on education in the first step, and (ii) the difference between within-MZ-twin FE estimates and within-DZ-twin FE estimates in the effect of education on marital outcomes in the second step, we are able to infer, albeit indirectly, the effects of earnings-related endowments on marital outcomes. The estimated effects inform us regarding the relationship between unobserved earnings-related endowments and observed spousal attributes such as age, height, education, and wage. We emphasize that our identification assumption is that the within-DZ-twin difference in earnings-related endowments is larger than the within-MZ-twin difference in earnings-related endowments, which is weaker than the conventional assumption in twin studies that MZ twins share identical endowments.

We apply this approach to estimate the effect of earnings-related endowments on various marital outcomes, using data from the Chinese Adult Twins Survey (CATS). The CATS is unique in that it includes a section on marriage in which respondents were asked to recall their own information and that of their spousal at wedding time, therefore, we are able to measure twins and their spousal attributes at the wedding time. Measures of individuals' attributes at wedding time may better reflect an individual's mate preferences than measures at other times. In the literature, one group of studies measures marital outcomes at the survey time after couples have been married for some period (Chiappori et al., 2012; Dupuy and Galichon, 2014; Zhang and Liu, 2003). However, these measures, such as earnings or health, may have been affected by the marriage itself. The other group of studies uses data from speed dating and measures the attributes of potential partners at the time of dating (Hitsch et al., 2010). Yet observed dating preferences at the time of dating do not fully reflect an individual's mate preference for the marital partner.

We first find that both men and women with higher earnings-related endowments have higher education, compared with their twin siblings with lower earnings-related endowments. Conditional on education, we further find that men with higher endowments and women with fewer endowments tend to marry earlier. The gender difference in the effect of earnings-related endowments on age at first marriage is consistent with the theoretical predictions of Siow (1998), but not those of Bergstrom and Bagnoli (1993).

We further find that one's unobserved earnings-related endowments significantly correlate with spousal observed attributes at wedding time, and that the correlations differ by gender and across specific measures of spousal attributes. First, men with higher earnings-related endowments marry younger wives, but no evidence shows that better endowed women marry younger husbands. Second, men with higher earnings-related endowments marry taller wives, but no evidence shows that better endowed women would marry taller husbands. Third, women with better earnings-related endowments tend to marry husbands with better education and higher wage, but no evidence shows that men with better earnings-related endowments prefer wives with better education and higher wage.

Our results remain robust to a series of sensitivity analyses. First, our results are not driven by measurement error associated with schooling years, which could induce potential attenuation bias. Following Ashenfelter and Krueger (1994), we use an instrumental variable (IV) method to check robustness and demonstrate that our results are robust. Second, we conduct factor analysis to validate the one-factor assumption underlying our analysis using the MZ-DZ twin experiment. Finally, we discuss alternative interpretations of unobserved endowments in the earning and marital outcome equations.

Our results have major implications for the literature on marital sorting and income inequality across households (Eika et al., 2019; Gonalons-Pons and Schwartz, 2017; Greenwood et al., 2014; Grönqvist et al., 2020), in addition to the literature on estimating marriage matching models. Researchers and policymakers have grown increasingly concerned about positive assortative mating in education, which raises household income inequality. We investigate the effect of unobservable earnings-related endowments on marital outcomes. We find that conditional on education, better endowed female twins tend to marry higher educated and better paid husbands, although better endowed male twins do not show such preferences. Therefore, income inequality across households would be exacerbated by other mate preferences, in addition to the channel through positive assortative mating in education.

The econometric method we develop contributes to the literature on twin studies. Behrman et al. (1994) use the MZ-DZ experiment to study the responsiveness of schooling to individual-specific endowments in the family and marriage market. Our paper differs from Behrman et al. (1994) in three aspects. First, we incorporate the MZ-DZ experiment in a regression framework, which allows us to flexibly control for covariates, while Behrman et al. (1994) adopt a variance decomposition method. Second, we focus on the marriage market, while they examine intrahousehold resource allocation. Third, we study the effects of men's and women's unobserved earnings-related endowments on their age at first marriage and spousal age, height, education, and wage measured at wedding time, while Behrman et al. (1994) study the effects of men's unobserved endowments on spousal education measured at survey time.

Finally, earlier studies using the MZ-DZ twin experiment implicitly assume that unobserved individual-specific endowments across earning and marital outcome equations can be summarized by one factor: the earnings-related endowment (Behrman et al., 1994; Li et al., 2010). We analyze this assumption and propose factor analysis to test its validity.

The rest of the paper is organized as follows. Section 2 describes the empirical strategy, Section 3 introduces the CATS data, and Section 4 presents the empirical results. Section 5 conducts robustness tests, and Section 6 concludes.

2 The MZ-DZ Twin Experiment

In this section, we exploit the MZ-DZ twin experiment and develop an econometric method to identify the effects of unobserved earnings-related endowments on schooling and marital outcomes.

2.1 Identification: Earning-related Endowments, Schooling, and Marital Outcomes

Schooling

We start with the following two equations:

$$y_{1j} = \alpha_0 + \alpha_1 Edu_{1j} + \mu_j + e_{1j} + \varepsilon_{1j}, \tag{1}$$

$$y_{2j} = \alpha_0 + \alpha_1 Edu_{2j} + \mu_j + e_{2j} + \varepsilon_{2j}, \tag{2}$$

where y_{ij} is the log monthly earning of twin i ($i = 1, 2$) in pair j; Edu_{ij} is years of schooling; μ_j is the unobservable family background shared by the twin pair; and e_{ij} is the unobservable individual-specific endowments related to earnings. Conditional on both unobservable μ_j and

e_{ij}, we assume the disturbance term ε_{ij} is i.i.d.[4] We assume that both μ_j and e_{ij} are normalized such that the coefficients before these two variables are one. Therefore, the better endowed twin sibling has a higher value of e_{ij}.

As μ_j and e_{ij} are unobservable, the OLS estimate of α_1 is biased if either μ_j or e_{ij} is simultaneously correlated with Edu_{ij} and y_{ij}. We attempt to use the within-MZ-twin FE method to address this issue. We assume that MZ twins are identical such that $e_{1j} = e_{2j}$, which we will discuss in detail later. Subtracting Eq. (2) from Eq. (1) for MZ twin pairs, we obtain

$$\Delta y_{ij} = \alpha_1^{MZ} \Delta Edu_{ij} + \Delta \varepsilon_{ij}, \tag{3}$$

where Δ is a within-twin difference operator. The coefficient α_1^{MZ} denotes the estimate of α using the MZ twin sample. As both μ_j and e_{ij} are removed from Eq. (3), ΔEdu_{ij} and $\Delta\varepsilon_{ij}$ are uncorrelated. So, $\alpha_1^{MZ} = \alpha$.

We then identify the sign of the effect of e_{ij} on Edu_{ij}. Subtracting Eq. (2) from Eq. (1) for DZ twin pairs, we get

$$\Delta y_{ij} = \alpha_1^{DZ} \Delta Edu_{ij} + \Delta v_{ij}, \tag{4}$$

where $\Delta v_{ij} = \Delta e_{ij} + \Delta \varepsilon_{ij}$. The coefficient α_1^{DZ} denotes the estimate of α using the DZ twin sample. ΔEdu_{ij} is correlated with Δv_{ij}. Applying the standard omitted variable bias formula, we derive

$$\alpha_1^{DZ} = \alpha_1 + \frac{Cov(\Delta Edu_{ij}, \Delta e_{ij})}{Var(\Delta Edu_{ij})}. \tag{5}$$

So,

$$\alpha_1^{DZ} - \alpha_1^{MZ} = \frac{Cov(\Delta Edu_{ij}, \Delta e_{ij})}{Var(\Delta Edu_{ij})}. \tag{6}$$

Therefore, $sign(Cov(\Delta Edu_{ij}, \Delta e_{ij})) = sign(\alpha_1^{DZ} - \alpha_1^{MZ})$ because $Var(\Delta Edu_{ij}) > 0$. By comparing α^{DZ} with α^{MZ}, we identify the sign of the effect of earning-related endowments on

4. We omit other covariates such as birth weight for simplicity of illustration. Our results remain almost the same when we control for birth weight.

education. For instance, if $\alpha_1^{DZ} - \alpha_1^{MZ} > 0$, $Cov(\Delta Edu_{ij}, \Delta e_{ij}) > 0$. Parents take a reinforcing strategy by allocating more schooling to the child with better earning-related endowments.

Marital outcomes

We then examine the effect of earning-related endowments on marital outcomes by considering the following equation:

$$G_{ij} = \beta_0 + \beta_1 Edu_{ij} + \delta\mu_j + \pi e_{ij} + \xi_{ij}, \tag{7}$$

where G_{ij} refers to the marital outcome of twin i in pair j. We are interested in five outcomes: age at first marriage, spousal age, spousal height, spousal education, and spousal wage at marriage, which are defined in the next section. Variables Edu_{ij}, μ_j, and e_{ij} are defined in the same way as in Eq. (1) or Eq. (2). ξ_{ij} is the error term.

The coefficient of β_1 measures the effects of education on marital outcomes, and π measures the effect of earning-related endowments on marital outcomes. To identify π, we compare within-MZ-twin FE estimates to within-DZ-twin FE estimates of β_1. In particular, taking the difference of Eq. (7) between the first and second twins for MZ twin pairs, we obtain

$$\Delta G_{ij} = \beta_1^{MZ} \Delta Edu_{ij} + \Delta\xi_{ij}. \tag{8}$$

Applying the OLS method to Eq. (8), we have $\beta_1^{MZ} = \beta_1$. Similarly, for DZ twins, taking the difference of Eq. (7) between the first and second twins, we have

$$\Delta G_{ij} = \beta_1^{DZ} \Delta Edu_{ij} + \Delta\varsigma_{ij}, \tag{9}$$

where $\Delta\varsigma_{ij} = \pi\Delta e_{ij} + \Delta\xi_{ij}$. As $\Delta\varsigma_{ij}$ is correlated with ΔEdu_{ij}, the estimate of β_1^{DZ} is biased due to unobservable individual-specific endowments. Applying the omitted variable bias formula, we have

$$\beta_1^{DZ} = \beta_1 + \pi * \frac{Cov(\Delta Edu_{ij}, \Delta e_{ij})}{Var(\Delta Edu_{ij})}. \tag{10}$$

Therefore,

$$\begin{aligned} \beta_1^{DZ} - \beta_1^{MZ} &= \pi * \frac{Cov(\Delta Edu_{ij}, \Delta e_{ij})}{Var(\Delta Edu_{ij})} \\ &= \pi * (\alpha_1^{DZ} - \alpha_1^{MZ}). \end{aligned} \tag{11}$$

We have

$$\pi = \frac{\beta_1^{DZ} - \beta_1^{MZ}}{\alpha_1^{DZ} - \alpha_1^{MZ}}, \tag{12}$$

where $\alpha_1^{DZ} - \alpha_1^{MZ}$ indicates the bias caused by the unobservable e_{ij} on the effect of education on earnings, and $\beta_1^{DZ} - \beta_1^{MZ}$ indicates the bias caused by e_{ij} on the effect of education on marital outcomes. Using Eq. (12), we thus identify π, which measures the effect of earning-related endowments on marital outcomes (see Eq. (7)). Specifically, we identify the sign of π from the signs of both $\beta_1^{DZ} - \beta_1^{MZ}$ and $\alpha_1^{DZ} - \alpha_1^{MZ}$. For instance, if $\alpha_1^{DZ} - \alpha_1^{MZ}$ and $\beta_1^{DZ} - \beta_1^{MZ}$ have the same sign, $\pi > 0$. The earning-related endowment is positively associated with G_{ij}: Compared with the less endowed twin sibling, the better endowed twin marries later, with a higher educated and taller spouse, and the spousal wage at marriage is higher. In contrast, if $\alpha_1^{DZ} - \alpha_1^{MZ}$ and $\beta_1^{DZ} - \beta_1^{MZ}$ have different signs, $\pi < 0$. This implies that the better endowed twin marries at a younger age, with a less educated, shorter spouse, and the spousal wage at marriage is lower. Please note that the sign of π has an economic interpretation, but not its magnitude, because we normalize e_{ij} in Eq. (1) and Eq. (2).

2.2 Regression Implementation

To facilitate making statistical inferences and flexibly controlling for observable characteristics at the individual level, we consider the following regression equation:

$$\Delta y_{ij} = \gamma_0 + \gamma_1 \Delta Edu_{ij} + \gamma_2 DZ_j + \gamma_3 \Delta Edu_{ij} * DZ_j + \Delta\epsilon_{ij}, \tag{13}$$

where DZ_j is a dummy variable indicating whether twin pair j is non-identical:[5] $DZ_j = 1$ if twin pair j is dizygotic or non-identical. For MZ twins, $DZ_j = 0$. The definitions of y_{ij} and Edu_{ij} are same as those in Eq. (1) and Eq. (2). We estimate Eq. (13) by pooling MZ and DZ twins. Thus, we have $\gamma_1 = \alpha_1^{MZ}$, $\gamma_1 + \gamma_3 = \alpha_1^{DZ}$, and $\gamma_3 = \alpha_1^{DZ} - \alpha_1^{MZ}$. Applying the OLS method to Eq. (13), we estimate γ_3 and its standard error.

With respect to marital outcomes (G_{ij}), we consider the following regression equation by pooling all MZ and DZ twins:

$$\Delta G_{ij} = \delta_0 + \delta_1 \Delta Edu_{ij} + \delta_2 \Delta DZ_j + \delta_3 \Delta Edu_{ij} * DZ_j + \Delta\zeta_{ij}, \tag{14}$$

where all variables are defined above. Thus, we have $\delta_1 = \beta_1^{MZ}$, $\delta_1 + \delta_3 = \beta_1^{DZ}$, and $\delta_3 = \beta_1^{DZ} - \beta_1^{MZ}$. Applying the OLS method to Eq. (14), we estimate δ_3 and its standard error. Furthermore, from Eq. (12), we have $\pi = \frac{\delta_3}{\gamma_3}$. That is, we identify π from the estimates of both δ_3 and γ_3.

As we focus on gender differences in the effect of endowments on marital outcomes, we estimate Eq. (13) and Eq. (14) for male and female twin pairs, respectively.

2.3 Potential Pitfalls

Omitted variables

5. In the regressions below, we include individual observed characteristics and their interaction terms with the DZ dummy.

A major concern with the twin method is the assumption that MZ twins share identical endowments, i.e., $e_{1j} = e_{2j}$. Although this assumption is commonly employed in the literature, it is not necessary for our identification. Our identification strategy relies on a much weaker assumption: Within-DZ-twin differences in endowments are larger than within-MZ-twin differences in endowments. Note that the key parameters in our paper are the *differences* between within-MZ-twin FE and within-DZ-twin FE estimates. We denote the within-MZ-twin difference in endowments as Δe_{ij}^{MZ}, and we use Δe_{ij}^{DZ} to denote the within-DZ-twin difference in endowments. Then, Eq. (6) becomes

$$\alpha_1^{DZ} - \alpha_1^{MZ} = \frac{Cov(\Delta Edu_{ij}, \Delta e_{ij}^{DZ} - \Delta e_{ij}^{MZ})}{Var(\Delta Edu_{ij})}. \tag{15}$$

As long as the within-DZ-twin difference in endowments is larger than the within-MZ-twin difference in endowments, the sign of the effect of endowments on schooling years can be inferred by comparing the within-twin FE estimate for DZ twins with that for MZ twins. A similar argument can be used to discuss identification of the sign of $\beta_1^{DZ} - \beta_1^{MZ}$.

Therefore, our identification assumption is weaker than the assumption that MZ twins have identical endowments, and is unlikely to be violated. MZ twins develop from a single fertilized egg, whereas DZ twins develop from two fertilized eggs. Therefore, MZ twins share the same polymorphic alleles, and DZ twins share, on average, 50% of their polymorphic alleles. DZ twins' genetic variations are larger than those of MZ twins, which has commonly been exploited by researchers who study the concordance rates of MZ and DZ twins to identify the genetic effects on epidemiology or human behaviors (Plomin et al., 2008).

Attenuation biases

A second concern with the twin method is potential measurement errors associated with self-reported years of schooling. Classical measurement errors introduce an attenuation bias with OLS estimates. This attenuation bias is exacerbated by the within-twin-FE method, because twin siblings' years of schooling are highly correlated (Ashenfelter and Krueger, 1994).

However, our within-twin FE estimates suffer little from this type of measurement error. The estimates of reliability ratios of schooling years in our study are higher than those reported by Ashenfelter and Krueger (1994), for instance, indicating that the problem of measurement error is less serious than in their samples. Moreover, differences in within-twin FE estimates between MZ and DZ twin samples are not affected by classical measurement errors under the assumption of the same distribution of measurement errors for MZ and DZ twins. Behrman et al. (1994) show that as long as measurement errors are drawn from the same distribution for both MZ and DZ twins, measurement errors in schooling years do not affect moment expressions such as Eq. (6) and Eq. (11). The classic measurement error also does not affect the comparison of within-MZ-twin FE estimates to within-DZ-twin FE estimates. Finally, to formally address the potential measurement error problem, following Ashenfelter and Krueger (1994), we use the IV method to check the robustness of our within-twin FE estimates. IV estimation results, reported in Section 5.1, show that our findings are not affected by measurement errors.

One-factor model and alternative interpretation of e_{ij}

We observe that the MZ-DZ model is a one-factor model, which means that the unobservable endowments in earning equation (Eq. (1)) are the same unobservable endowments in the marital outcome equation (Eq. (7)). Thus, we have two concerns with this one-factor assumption used by Behrman et al. (1994). One concern is whether there are more than one unobservable factors that simultaneously affect earnings and marital outcomes. The dependent variable in the earning equation (Eq. (1)) is log monthly earnings. In addition to unobservable earning-related endowments, monthly earnings might be affected by unobservable marital attributes, which also appear in the marital outcome equation (Eq. (7)). We use the factor analysis method to explicitly test the assumption on a common factor that appears in both the earning and marital outcome equations in Section 5.2. The other concern is whether there are alternative interpretations of endowments e_{ij}, which we discuss in Section 5.3.

3 Data

3.1 The Chinese Adult Twins Survey (CATS)

Our data are derived from the CATS, which was carried out by the Urban Survey Unit (USU) of the National Bureau of Statistics (NBS) in June and July of 2002 in five cities in China. Based on twin questionnaires from the United States and elsewhere, the survey covers a wide range of socioeconomic factors. The questionnaire was designed by Mark Rosenzweig and Junsen Zhang in consultation with experts on twin studies and Chinese experts from the NBS. Adult twins aged 18 to 65 were identified by the local statistical bureaus through various channels, including colleagues, friends, relatives, newspaper advertising, neighborhood notices and management committees, and household records from the local public security bureau. Together, these channels create a roughly equal probability of contacting all twins in those cities; thus, the sample obtained is representative of twin pairs who reside in the same city. Questionnaires were completed through face-to-face personal interviews.

The CATS is the first socioeconomic twin data set in China, and perhaps the first in Asia. The data set offers rich information on the socioeconomic status of respondents in the five cities of Chengdu, Chongqing, Harbin, Hefei, and Wuhan. A total of 3,012 individuals are twins, which include two sets of triplets. We distinguish whether the twins are MZ or DZ twin pairs. We consider a pair of twins to be identical if both twins respond that they have the identical hair color, appearance, and gender. In our empirical analysis, we include only MZ twin and DZ twin pairs of the same gender.

We consider two major advantages of using the CATS for our empirical analysis. First, from a methodological view, the CATS facilitates application of the MZ-DZ twin model to estimate the effect of endowments on marital outcomes. This is because within-DZ-twin differences in endowments are larger than within-MZ-twin differences. The within-MZ-twin FE estimate is less biased due to unobserved endowments compared with the within-DZ-twin FE estimate. By adopting an MZ-DZ model, we are able to infer the signs of the effects of unobserved endowments on marital outcomes.

Second, the CATS contains detailed information on the twins and their spouses at the time they got married, including age at first marriage, education, height, and monthly wage. Thus, it enables us to measure marital outcomes at the wedding time. This is important, because observed health status or earnings at survey time might have been affected by the spouse or marriage itself. For example, Huang et al. (2009) find that spousal education enhances a person's earnings through a cross-spousal productivity effect. To partly address this issue, Chiappori et al. (2012) select only recently formed couples who have been married for no more than 3 years. Dupuy and Galichon (2014) include only couples in which the wife is younger than 40 years old. Compared with attributes measured after marriage, measures of attributes at the marriage time may better reflect a person's mating outcomes.

We have 830 twin pairs (1,660 individuals) with complete information for our analysis. We have dropped individuals who are not married and twin pairs who do not have complete information on themselves and their spouses. We split the sample into two subsamples; one contains women and the other contains men. In total, we have 426 male twin pairs (852 individuals) and 404 female twin pairs (808 individuals).

3.2 Summary Statistics

Table 1 presents summary statistics by gender and twin type. Column (1) presents the means of all variables for all twins. Spousal information at the wedding time is presented in Panel A. On average, spouses of twins married at 26 years old, had 11 years of schooling, with height of 165 centimeters. Their monthly wage (normalized to 2002 yuan) was 312 yuan when they married. Panel B presents twins' own information at the wedding time. On average, twins married at age 26, had 11 years of schooling, with height of 164 centimeters, and earned 314 yuan at the wedding time (normalized to 2002 yuan). Panels C and D show that twins were 42 years old at survey time, and had monthly earnings of 917 yuan in 2002, which include wages, bonuses, and subsidies. The average birth weight is 2.39 kg.

Columns (2) and (5) present summary statistics for male and female twins, respectively. On average, male twins married 2 years earlier than female twins. Female twins' years of schooling are slightly above male twins'. Male twins earned more than female twins did in terms of both monthly wage at the wedding time and the monthly earnings at survey time. Husbands were 2 years older than their wives, around 10 centimeters taller than their wives, and had slightly more education and higher monthly wage at the wedding time than their wives.

We also present summary statistics for MZ twins and DZ twins separately for male twins and female twins. Columns (3) and (4) show descriptive statistics for MZ and DZ male twins, respectively. The differences between MZ and DZ male twins in these statistics are negligible. For the female twins sample, differences between MZ and DZ twins are also minimal, as shown in Columns (6) and (7).

We examine the representativeness of the twin sample by comparing our CATS data with other three data sets. We first use data from the Chinese Non-Twin Survey (CNTS). When conducting the CATS, for purposes of comparison, the same questionnaire was administered to a non-twin sample. The non-twin households in this sample were also surveyed by the USU of the NBS in the same year and same five cities as in the CATS. The corresponding summary statistics for the non-twin sample are presented in Table A1 in the appendix. The differences in those statistics between the twin sample and non-twin sample are minimal, except for birth weight. We also use other two data sets for comparison, extracted from the 1% China population census in 2000 and 20% sampling of the China population mini-census in 2005. We restrict the data to those married couples who are in the same age interval in 2002 and live in urban areas of the same five cities as the in the CATS. The census data cover information about birth year, age at first marriage, and education. Summary statistics are presented in Table A2 in the appendix, and are similar to those for twin sample.

3.3 Within-twin Variation in Schooling Years

The CATS data offer us sufficient within-twin variations in schooling years to conduct the within-twin FE estimation. Table 2 shows that 49.7% of female twin pairs have different schooling years: 28.9% have 0-2 years of difference in years of schooling; 19.6% have 2-5 years of difference; and 2% have a difference of more than 5 years. Similarly, 46% of male twin pairs do not have the same schooling years: 25.8% have 0-2 years of difference; 18.1% have 2-5 years of difference; and 2% have a difference of more than 5 years.

4 Empirical Results

In this section, we report estimates of the effects of earning-related endowments on schooling years and marital outcomes, including one's own age at first marriage and spousal age, height, education, and wage.

4.1 Years of Schooling

Before presenting estimation results on marital outcomes, we examine the effect of earning-related endowments on education. Table 3 reports the within-twin FE estimates of Eq. (13) for male and female twins. The dependent variable is the within-twin difference of log monthly earnings.

We are interested in the coefficients on the interaction term ($\Delta Education * DZ$), which captures the difference between the within-DZ-twin FE estimate and within-MZ-twin FE estimate of return to schooling. Columns (1) and (2) show the results for male twins. Estimated coefficients on the interaction term are consistently positive and statistically significant. The within-twin FE estimate of return to education for DZ twins is larger than that for MZ twins, i.e., $\alpha_1^{DZ} - \alpha_1^{MZ} > 0$. Columns (3) and (4) of Table 3 present estimates for female twins. Both estimates of the coefficient on the interaction term are also positive and statistically significant at the 5% level.

According to Eq. (6), the covariance between the within-twin difference of education and the difference of earning-related endowments, i.e., $Cov(\Delta Edu_{ij}, \Delta e_{ij})$, has the same sign as the difference in within-twin FE estimates between DZ and MZ twins, i.e., $\alpha_1^{DZ} - \alpha_1^{MZ}$. The positive coefficient on the interaction term indicates that the effect of earning-related endowments on education is positive. This result is in line with previous findings by Behrman et al. (1994) and Yi et al. (2015). Parents adopt a reinforcement strategy for the investment in schooling for their children with respect to earning-related endowments.

The sign of the effect of earning-related endowments on marital outcomes (π) depends on the signs of both $\alpha_1^{DZ} - \alpha_1^{MZ}$ and $\beta_1^{DZ} - \beta_1^{MZ}$. As $\alpha_1^{DZ} - \alpha_1^{MZ} > 0$ for both men and women, the effect of earning-related endowments on marital outcomes (π) has the same sign as the difference in within-twin FE estimates between DZ and MZ twins in the marital outcome equation, i.e., $\beta_1^{DZ} - \beta_1^{MZ}$.

4.2 Marital Outcomes[6]

Age at first marriage

We now examine the effect of earning-related endowments on the timing of marriage. Table 4 reports the within-twin FE estimates of Eq. (14), in which the dependent variable is the within-twin difference in the twin's own age at first marriage.

Estimates of the coefficient on the interaction term for male twins are negative and statistically significant, as shown in Columns (1) and (2), indicating that the within-twin FE estimate of the effect of education on age at first marriage for DZ twins is smaller than that for MZ twins, i.e., $\beta_1^{DZ} - \beta_1^{MZ} < 0$. Based on Eq. (12) and that $\alpha_1^{DZ} - \alpha_1^{MZ} > 0$, we conclude that the effect of earning-related endowments on age at first marriage for men is negative. Conditional

6. In Table A3 in the appendix, we report OLS estimates of education on the marital outcomes for both the twins sample (Panel A) and non-twin sample (Panel B). Differences in the estimates are minimal between the two samples, indicating that the twin sample is representative.

on education, the better endowed male twin tends to marry earlier, compared with the twin with fewer earning-related endowments. [7]

By contrast, for women, we observe positive and statistically significant estimates of the coefficient on the interaction term in Columns (3) and (4). The within-twin estimate of the effect of education on age at first marriage for DZ female twins is larger than that for MZ female twins, i.e., $\beta_1^{DZ} - \beta_1^{MZ} > 0$. Therefore, the effect of earning-related endowments on age at first marriage for women is positive. Conditional on education, compared with the twin with fewer endowments, the better endowed female twin tends to marry at an older age.

Our estimates show that unobserved endowments affect men's and women's timing of marriage differently. The literature has theoretically explored how earning-related ability affects the timing of first marriage from three perspectives, although researchers have yet to achieve a consensus. First, from the perspective of the marriage theory of Becker (1973), husbands and wives are substitutes in the labor market and home production. Consequently, men with higher earning-related ability and women with lower earning-related ability have greater gains from marriage. Therefore, men with lower earning-related ability and women with higher earning-related ability marry at an older age. The second perspective is from the asymmetric information assumption of Bergstrom and Bagnoli (1993). They suggest that in the marriage market, women put more weight on the earning-related ability of men, whereas men care more about the fecundity of women. Earning-related ability is not easy to observe, whereas the advantaged traits of women can be observed at a younger age. Consequently, men with higher earning-related ability tend to marry at an older age, but there is no benefit for women to marry later. Third, Siow (1998) theoretically derives that the differential fecundity between men and women causes age at first marriage for women, on average, to be lower than that for men, and leads men with

7. Columns (1) and (2) of Table 4 suggest that within-twin FE estimates of the effect of education on age at first marriage are negative for DZ male twins, because the estimates of coefficients on the interaction term (i.e., $\beta_1^{DZ} - \beta_1^{MZ}$) are negative, and their absolute values are larger than the positive estimates of coefficients on education (i.e., β_1^{MZ}). We checked the OLS estimates of education on age at first marriage for the sample sample, which are positive and statistically significant (results are available upon request). Compared with within-DZ-twin FE estimates, the OLS estimates are further confounded by unobservable family background.

higher earning-related ability to marry earlier.

Our finding indicates that men with high earning-related ability and women with lower earning-related ability tend to marry earlier conditional on education. This result is in line with Becker (1973) and Siow (1998) but not Bergstrom and Bagnoli (1993). One potential explanation is that earning-related endowments, which are unobserved by researchers, may be observed by potential partners in the marriage market. Another potential explanation is related to the opportunity cost of delaying marriage for men and that of early marriage for women, which is not modeled in Bergstrom and Bagnoli (1993). For example, men with high earning-related ability may have benefited more from household specialization if they had got married earlier. By contrast, if women with high earning-related ability enter into marriage early, they may be worse off in the labor market due to childbearing and childcare (Adda et al., 2017; Myoung, 2016).

Spousal age

We also investigate the effects of earning-related endowments on spousal age. Columns (1)-(4) in Table 5 present the results for male twins. We observe that the estimate of the coefficient on the interaction term is -0.39 and significant at the 1% level (Column (1)). The within-DZ-twin FE estimate of the effect of education on spousal age is statistically smaller than the within-MZ-twin FE estimate, i.e., $\beta_1^{DZ} - \beta_1^{MZ} < 0$. Thus, according to Eq. (12), combined with the positive effect of earning-related endowments on education (i.e., $\alpha_1^{DZ} - \alpha_1^{MZ} > 0$), we infer that $\pi < 0$—that is, earning-related endowments have a negative effect on spousal age for male twins. Conditional on education, better endowed men tend to marry younger wives compared with their less endowed brothers. The result remains robust when controlling only for one's own birth weight (Column (2)), only for age at first marriage (Column (3)), and both of these two variables (Column (4)). We thus conclude that men with higher earning-related endowments prefer younger wives.

By contrast, for women, estimates of the coefficient on the interaction term are positive but statistically insignificant (Columns (5)-(8)). We suggest that the effect of earning-related endowments on spousal age for women is positive (i.e., $\pi > 0$). Thus, no significant evidence shows that better endowed women prefer young husbands.

The gender difference in preference for spousal age is consistent with the theoretical analysis of Siow (1998) and empirical findings of Choo (2015). Siow argues that women are fecund for a shorter period of their lives than men, and fecund women are relatively scarce compared with men in the marriage market. Men consider the fecundity of their partner, and thus prefer younger women. Choo develops a dynamic model to estimate the marriage gain based on the static model of Choo and Siow (2006). Choo finds that men match with considerably younger women to maximize their dynamic marriage gains; in contrast, women would match with slightly older men.

Spousal height

We examine the effect of earning-related endowments on spousal height, which is used as a proxy variable to measure physical attractiveness. Table 6 reports the results. The dependent variable is the within-twin-difference in spousal height. Previous studies have found positive assortative mating in height between couples (Becker, 1973; Dupuy and Galichon, 2014; Hitsch et al., 2010). Therefore, all regression specifications control for the within-twin difference in twin's own height and its interaction with the DZ dummy.

For male twins, as reported in Columns (1)-(4), estimates of the coefficient on the interaction term are positive and statistically significant, i.e., $\beta_1^{DZ} - \beta_1^{MZ} > 0$. These results suggest that conditional on education, men with higher earning-related endowments marry taller wives.

Results of the estimation for women in Columns (5)-(8) show that estimated coefficients on the interaction term are negative and statistically insignificant. We cannot reject the null hypothesis that the within-twin FE estimate of the effect of education on spousal height for MZ twins is the same as that for DZ twins. We do not find any significant evidence that better endowed women would marry taller husbands than their twin sisters with less earning-related endowments when we control for education.

The opposite signs of estimated coefficients on the interaction term highlight the gender difference in the preference for spousal height. Men with higher earning-related endowments prefer taller partners, whereas better endowed women do not show such a preference in height. This finding is inconsistent with that of Hitsch et al. (2010), which is based on online dating data from the US. They find that men typically avoid tall women, while women have a preference for tall men. The difference between our finding and Hitsch et al.'s (2010) may reflect the cultural difference between Eastern and Western societies.

Spousal education

We also investigate how earning-related endowments are associated with spousal education. Table 7 replicates Table 5 by using within-twin difference in spousal education as the dependent variable. Columns (1)-(4) of Table 7 report estimates for male twins. Estimated coefficients on the interaction term for men are negative but statistically insignificant. Therefore, we do not find any significant evidence that conditional on education, better endowed men tend to marry better educated wives.

By contrast, for women, estimates of the coefficients on the interaction term are positive and statistically significant at the 5% confidence level (Columns (6)-(8)). For female twins, earning-related endowments have a positive effect on spousal education. Thus, we conclude that, controlling for education, women with better earning-related endowments marry more highly educated husbands, compared with their less endowed twins.

Men care less about the education of their spouses, whereas women with higher earning-related endowments show a strong preference for better educated men. Our finding is consistent with the finding that women with higher levels of education are not necessarily more attractive in the marriage market (Boulier and Rosenzweig, 1984). Hitsch et al. (2010) show that although men and women want to marry a partner with a similar education level, men generally avoid marrying more highly educated women. Women have an overall strong preference for an educated husband, but also have a relatively small tendency to avoid men who are more educated than themselves.

Spousal wage

Finally, we investigate the effect of earning-related endowments on spousal wage. Results are presented in Table 8, in which the dependent variable is the within-twin difference in log spousal monthly wage at the wedding time. In Columns (1)-(4), the estimated coefficients on interaction term for male twins are negative but statistically insignificant. Therefore, we do not find significant evidence that, controlling for education, better endowed men tend to marry wives with higher wage.

By contrast, the estimated coefficients on the interaction term for women are positive and statistically significant (Columns (5)-(8)). Controlling for education, women with better earning-related endowments would like to marry husbands who have higher wage, compared with their less endowed twin sisters.

We conclude that men with higher earning-related endowments do not prefer wives with higher wage, whereas women with higher endowments exhibit strong preference for men with higher wage. These results are consistent the literature on gender differences in the preferences of partners in the marriage market. Men prefer partners who are less ambitious than they are (Fisman et al., 2006). By contrast, women place nearly twice as much weight on income than men (Hitsch et al., 2010). Ambition in women is less desirable in the marriage market; thus, single women may pretend to be less ambitious and give up certain career-enhancing actions. This situation continues even after marriage. A woman who earns more than her husband is relatively rare, and when she does, marital satisfaction is low and divorce is more likely (Bertrand et al., 2016, 2015).

5 Robustness

We conduct our robustness analyses in this section. We first carry out IV estimation to address potential measurement errors. We then test the one-factor assumption underlying the MZ-DZ model. Finally, we discuss alternative interpretations of unobservable endowments.

5.1 IV Estimations

As discussed in Section 2.3, the measurement error associated with self-reported schooling years is an important issue for within-twin FE estimation. In this section, we follow the method of Ashenfelter and Krueger (1994) to construct the IV and check the robustness of our estimates with respect to potential measurement errors.

In our survey, we ask each twin about their own schooling years and the schooling years of their co-twin siblings. Thus, the within-twin difference in schooling years ΔS_j, where j indicates twin pair j, can be constructed in four ways. To simplify, we omit the twin pair subscript j. We write S_i^k for twin $i's$ schooling years reported by twin k. The true schooling difference is denoted as ΔS. We summarize four ways to calculate the within-twin difference in schooling years:

$$\text{Self-report difference: } \Delta S' = S_1^1 - S_2^2 = \Delta S + \Delta \varrho',$$

$$\text{Cross-report difference: } \Delta S'' = S_1^2 - S_2^1 = \Delta S + \Delta \varrho'',$$

$$\text{Twin 1-report difference: } \Delta S^* = S_1^1 - S_2^1 = \Delta S + \Delta \varrho^*,$$

$$\text{Twin 2-report difference: } \Delta S^{**} = S_1^2 - S_2^2 = \Delta S + \Delta \varrho^{**}.$$

Here, $\Delta \varrho$ represents the difference in measurement errors; $\Delta S'$ is the difference between the self-reported schooling years of twin 1 and the self-reported schooling years of twin 2; $\Delta S''$ is the difference between the schooling years of twin 1 reported by twin 2 and the schooling years of twin 2 reported by twin 1; and ΔS^* (ΔS^{**}) is the difference between twin 1's (twin 2's) report of his or her own schooling years and his or her (twin 2's) report of the twin sibling's schooling years.

Following Ashenfelter and Krueger (1994), we first use $S_1^1 - S_2^2$ as the regressor and $S_1^2 - S_2^1$ as the IV. We call this IV method the IV1 model. If measurement error $\Delta\varrho''$ in $\Delta S''$ is correlated with measurement error $\Delta\varrho'$ in $\Delta S'$, estimates by the IV1 model remain biased. To overcome this problem, we use another IV method. That is, we use the twin-1 report difference in schooling years ΔS^* as the regressor, and twin 2-report difference ΔS^{**} as the IV. We call this method the IV2 model.

Before presenting the estimates, we examine the correlation of schooling years between twin siblings. The correlation coefficient between schooling years of twin 1 reported by himself/herself and that by the co-twin sibling, i.e., $Corr(S_1^1, S_1^2)$, is 0.95 in our sample. The correlation coefficient between self-reported schooling years and co-twin sibling reports of schooling years for the second twin, i.e., $Corr(S_2^2, S_2^1)$, is 0.94. Compared with the correlation coefficients (0.88 and 0.92) of Ashenfelter and Krueger (1994), the correlation coefficients in our study are bigger, which indicates that the problem of measurement error is less serious. Moreover, the large correlation coefficients suggest that co-twin-reported schooling years serve as a good IV for self-reported schooling years in our study.

Columns (1) and (2) in Table A4 in the appendix show the estimates of Eq. (13) by IV1 model for male twins, and Columns (5) and (6) for female twins. $\Delta Education$ is the difference in self-reported schooling years ($\Delta S'$). We use cross-report difference in schooling years ($\Delta S''$) as the IV for $\Delta S'$. Comparing the estimates in Table A4 with those in Table 3, we find that measurement error biases FE estimates of return to schooling downward. Nevertheless, estimate coefficients on the interaction term remain positive and statistically significant.

Considering that the measurement error in $S_1^1 - S_2^2$ is probably correlated with the measurement error in $S_1^2 - S_2^1$, we use the IV2 model to check the robustness of our IV1 estimates. IV2 estimates for male twins are shown in Columns (3) and (4), and those for female twins in Columns (7) and (8). Estimated coefficients on the interaction term remain positive and statistically significant for both men and women. We thus conclude that the measurement error in schooling years does not affect the sign of the estimated coefficients on the interaction term in Eq. (13). This conclusion holds for both men and women.

We also check whether our findings of marital outcomes are affected by measurement error. We present detailed results of the IV1 model in Tables A5-A9 in the appendix for all marital outcomes. For simplicity, we will now discuss the results for age at first marriage. The explanation of estimation results for other marital outcomes by the IV1 model is similar.

Table A5 in the appendix presents IV estimates in Eq. (14) when the dependent variable is within-twin difference in age at first marriage. In row (1), the magnitudes of the estimated effect of education on age at first marriage are slightly larger than those presented in Table 4. Measurement error biases the impacts of education on age at first marriage downward. Nevertheless, estimates of the coefficient on the interaction term for men are statistically significantly negative, whereas estimates for women are positive and statistically significant. Positive estimates of the coefficient on the interaction term are robust compared with those in Table 4. Measurement error does not change the signs of the coefficient on the interaction term. Conditional on education, men who have better earning-related endowments tend to marry at a younger age, and better endowed women are likely to enter into marriage at an older age, compared with their less endowed twins.

Results of the robustness check using the IV2 model are quite similar to those using the IV1 model. We summarize the results using the IV2 model in Table A10 in the appendix. To save space, we only report estimates of the coefficient on the interaction term and omit reporting coefficients on other variables. Results using the IV2 model are robust compared with those using the IV1 model. In sum, our findings are robust and are not driven by measurement error.

5.2 Testing the One-factor Model

We conduct the factor analysis to check the validity of the assumption underlying the MZ-DZ model: There exists only one factor to summarize unobservable twin-specific endowments (e_{ij}) across earning and marital outcome equations. Our empirical analysis yields six outcomes: earning, age at first marriage, spousal age, spousal height, spousal education, and spousal wage. We first compute the regression "residual" in each outcome equation for DZ twins—that is, $\Delta \upsilon_{ij}$ in the earning equation and $\Delta \zeta_{ij}{}'s$ in the five marital outcome equations. These residuals are calculated by plugging within-MZ-twin FE estimates of coefficients into the corresponding equation for DZ twins. We assume that within-MZ-twin FE estimates are consistent, but within-DZ-twin FE estimates are biased due to unobservable endowments e_{ij}. Therefore, using within-MZ-twin FE estimates to calculate these residuals for DZ twins can capture information on endowments for each outcome inside the error term ($\Delta \upsilon_{ij} = \Delta e_{ij} + \Delta \epsilon_{ij}$ and $\Delta \zeta_{ij} = \pi \Delta e_{ij} + \Delta \xi_{ij}$).

Using the earning equation as an example, we describe how to construct the regression residual for DZ twins in detail. By applying the OLS regression on Eq. (3) for MZ twins, we obtain a consistent estimate of return to education, denoted $\hat{\alpha}_1^{MZ}$. Then, by using this estimate, we calculate the residual for DZ twins, that is, $\Delta \upsilon_{ij} = \Delta y_{ij} - \hat{\alpha}_1^{MZ} * \Delta Edu_{ij}$. Similarly, we calculate the other five residuals for DZ twins.

We then study the number of common factor(s) among the six residuals by using exploratory factor analysis (EFA), which is a statistical method used to identify the underlying relationship between observed variables. In particular, the EFA uses a small number of unobserved variables called "factors" to describe variability among a battery of observed and correlated variables. Our null hypothesis is that there exists only one common factor among these six variables.

There are two main EFA methods: principal axis factoring (PAF) and maximum likelihood (ML). We use both methods in this paper. For the former, a variety of criteria in the literature are provided to decide the number of common factors, such as Cattell's scree test,[8] the Guttman-Kaiser rule,[9] and parallel analysis (PA).[10] Of these three criteria, the PA is viewed as one of the most accurate methods for determining the number of factors to retain (Hayton et al., 2004; Ledesma et al., 2007; Thompson, 2004; Zwick and Velicer, 1986).

Figure A1 in the appendix shows the results of the PA. The solid line connects the values of eigenvalues by PAF. The dashed line connects the values of eigenvalues obtained from random data. There is only one factor whose PCA eigenvalue is above the PA eigenvalue for both male and female twin samples.

We also apply the ML method to choose the number of factors to retain. The ML method was developed by Bartlett (1950, 1951) and preferred by researchers such as Tucker and Lewis (1973), Velicier and Jackson (1990), and Costello and Obsorne (2005). Table A11 in the appendix reports the results of Bartlett's test for the six residuals for DZ twins. We first test the null hypothesis that no common factors exist. The p-value of chi-square is 0.0000 for males, which indicates that we reject the null hypothesis at the 1% level. At least one common factor out of the six residuals for male DZ twins exists. We then test whether one factor is sufficient to express these six residuals. The p-value of chi-square for male DZ twins is 0.4592. Thus, we cannot reject the null hypothesis. One factor is sufficient to capture information on the six residuals for male DZ twins. Similarly, from the results in the second row, we conclude that only one common factor exists out of the six residuals for female DZ twins.

The ML method also enables us to describe the goodness of model fit. We use two criteria, the Akaike information criterion (AIC) and the Bayes information criterion (BIC), for the ML method. For a set of models with different numbers of factors estimated by ML, smaller AIC

8. Cattell's scree test (Cattell, 1966) must define the cutoff point between important and trivial factors, and has long been criticized for its subjectivity (Hayton et al., 2004; Zwick and Velicer, 1986).

9. The Guttman-Kaiser-rule (Guttman, 1954; Kaiser, 1960, 1961) states that only factors that have eigenvalues greater than one are retained for interpretation. Although it is easy to implement, this method has been challenged with respect to theoretical justification and empirical evaluation. The rule is well known to overestimate the number of factors (Thompson, 2004; Zwick and Velicer, 1986), rendering it less informative than other methods.

10. The PA was developed by Horn (1965). Principal component analysis (PCA) eigenvalues that are greater than their respective component PA eigenvalues from random data would be retained. All components with eigenvalues below their respective PA eigenvalue threshold are probably spurious (Franklin et al., 1995).

or BIC values indicate a better fit. We report the values of AIC and BIC for different models in Table A12 in the appendix. The AIC value for the model with only factor is 20.98 for male twins, which is the smallest compared with the other two models with 2 or 3 factors. Moreover, the BIC value for the one-factor model is also the smallest for male twins. Thus, the one-factor model fits the six residuals for male DZ twins. Similarly, comparison of the values of AIC and BIC for female twins shows that the one-factor model is the best for female twins.

Results using the PAF and ML methods suggest that the one-factor model is the best model to fit the six residuals for DZ twins. These conclusions hold for both male and female twins. Therefore, our factor analysis results validate the one-factor assumption of the MZ-DZ model.

5.3 An Alternative Interpretation

We interpret unobservable endowments e_{ij} in Eq. (1) as earning-related ability. Meanwhile, endowments also affect marital outcomes in Eq. (7). An alternative interpretation of e_{ij} might be "marital attractiveness." For example, physical appearance is one of the most important indications of marital attractiveness. Good-looking people are more attractive in the marriage market than plain people; they also earn more in the labor market than plain people (Hamermesh and Biddle, 1994). Other attributes related to marital attractiveness may also be correlated with earnings. Based on findings in the literature that marital attractiveness is positively correlated with earnings, the empirical results in this study might be interpreted in another way. Conditional on education, men with higher marital attractiveness marry earlier, and have younger and taller—but not higher education or higher income—wives, compared with their less attractive twin brothers. By contrast, women with higher marital attractiveness marry at an older age, with better educated and better paid—but not taller or younger—husbands, compared with their less attractive twin sisters. We may consider this interpretation to be less appealing, however, because it is difficult to rationalize why more attractive women marry later.

6 Conclusion

We use the MZ-DZ model to identify gender differences in the effect of earning-related endowments on marital outcomes in urban China. We find that men and women care about different attributes when choosing a marriage partner. Men put weight on the physical attractiveness of their spouses, such as youthfulness (age) and height. Conditional on education, higher endowed men tend to marry earlier than their less endowed twin sibling, and their wives tend to be younger and taller. In contrast, women care about the education and wage of their husband. Compared with their less endowed twin sibling, women with better endowments marry at an older age, with higher educated husbands who also have a higher wage at the time of marriage.

Our findings suggest that the boom in female higher education has significant implications for the marriage market (Becker et al., 2010; Chiappori et al., 2017). The increase in women's education augments their earning capacity, which may delay women's timing for their first marriage. Moreover, marriage for women, particularly for those highly educated, may decrease with the boom in female higher education. In past decades, the increase in men's education has been slower than that in women's (Bailey and DiPrete, 2016). Highly educated women, therefore, may not be able to find men with high education and salary to marry.

Our study has two main limitations. First, the MZ-DZ model proposed by Behrman et al. (1994) relies on the linear additive assumption. Therefore, we are not able to construct a full marriage matching model to allow for interactions between unobservable and observable attributes in the matching process. Estimating such a full model depends on the development of non-additive fixed-effects econometrics. Second, we identify gender differences in the effect of earning-related endowments on marital outcomes, but do not explore the causes of such differences. Bertrand et al. (2015) suggest that gender differences in preferences of a spouse may result from social attitudes and social identity norms, some of which significantly affect prarents' investment in girls' education (Ashraf et al., 2020). More research would be warranted to analyze the causes.

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TABLE 1
Summary Statistics

	All Twins	Male Twins			Female Twins		
		Total	MZ	DZ	Total	MZ	DZ
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: Information on twin's spouse at wedding time							
Spousal age	25.60	24.38	24.37	24.41	26.88	26.90	26.84
	(2.88)	(2.42)	(2.44)	(2.39)	(2.76)	(2.85)	(2.60)
Spousal schooling years	11.18	10.75	10.86	10.54	11.63	11.62	11.66
	(2.63)	(2.46)	(2.49)	(2.38)	(2.72)	(2.68)	(2.79)
Spousal height (centimeters)	165.38	160.02	160.03	159.99	171.03	171.07	170.96
	(7.31)	(4.71)	(4.82)	(4.48)	(4.91)	(4.80)	(5.10)
Spousal monthly wage (2002 yuan)	311.47	266.42	270.60	258.16	358.97	342.19	388.96
	(408.72)	(385.39)	(431.88)	(271.33)	(427.08)	(431.18)	(418.72)
Panel B: Information on twin at wedding time							
Age	25.83	26.89	26.89	26.88	24.71	24.71	24.69
	(2.90)	(3.00)	(2.96)	(3.09)	(2.30)	(2.25)	(2.38)
Education	11.24	11.10	11.15	11.00	11.39	11.35	11.45
	(2.59)	(2.68)	(2.73)	(2.57)	(2.50)	(2.50)	(2.49)
Own height (centimeters)	163.69	169.13	168.83	169.71	157.96	157.98	157.92
	(7.74)	(5.84)	(5.99)	(5.49)	(4.80)	(4.69)	(4.98)
Monthly wage (2002 yuan)	313.93	353.34	345.05	369.72	272.38	255.19	303.09
	(370.81)	(420.41)	(443.55)	(370.56)	(304.82)	(250.79)	(381.40)
Panel C: Information on twin at the survey time (2002)							
Age in 2002	41.54	41.55	42.23	40.20	41.53	42.07	40.57
	(8.19)	(8.22)	(7.87)	(8.73)	(8.15)	(8.12)	(8.14)
Monthly earnings in 2002	916.64	1,012.89	1,017.59	1,003.58	815.15	800.44	841.41
	(1,150.31)	(1,394.58)	(1,405.35)	(1,375.42)	(805.73)	(856.94)	(705.72)
Panel D: Information on twin at birth							
Birth weight (kg)	2.39	2.47	2.48	2.45	2.30	2.31	2.28
	(0.60)	(0.64)	(0.68)	(0.55)	(0.55)	(0.53)	(0.58)
Twin pairs	830	426	283	143	404	259	145
Observations	1660	852	566	286	808	518	290

Notes: Mean and standard deviation (in parentheses) are reported in the table.

TABLE 2
Within-twin Difference in Schooling Years

Within-twin Difference	Male Twins		Female Twins		Total	
in Schooling Years	Count	Percent	Count	Percent	Count	Percent
0	230	53.99	203	50.28	433	52.17
(0,1]	56	13.15	71	17.57	127	15.30
(1,2]	54	12.68	46	11.39	100	12.05
(2,3]	56	13.15	56	13.86	112	13.49
(3,5]	23	5.04	23	5.69	46	5.54
5+	7	1.64	5	1.24	12	1.45
Total pairs	426	100	404	100	830	100

TABLE 3
Endowments and Earnings

	Dependent variable: ΔLog monthly earnings			
	Men	Men	Women	Women
	(1)	(2)	(3)	(4)
ΔEducation	0.0430**	0.0424**	0.0495**	0.0465**
	(0.0205)	(0.0205)	(0.0234)	(0.0230)
ΔEducation*DZ	0.0873**	0.0878***	0.0922**	0.0965**
	(0.0337)	(0.0332)	(0.0394)	(0.0394)
DZ	Yes	Yes	Yes	Yes
ΔBirth weight	No	Yes	No	Yes
ΔBirth weight*DZ	No	Yes	No	Yes
Twin pairs	426	426	404	404
Observations	852	852	808	808
R^2	0.06	0.07	0.06	0.07

Notes: Here Δ is a within-twin difference operator. Δ*Education* is the difference between the self-reported schooling years for twin 1 and self-reported schooling years for twin 2. Robust standard errors are in parentheses. * Significant at the 10% level. ** Significant at the 5% level. *** Significant at the 1% level.

TABLE 4
Endowments and Age at First Marriage

	Dependent variable: ΔAge at First Marriage			
	Men	Men	Women	Women
	(1)	(2)	(3)	(4)
ΔEducation	0.2098**	0.2003**	0.2168**	0.2219***
	(0.0936)	(0.0939)	(0.0845)	(0.0849)
ΔEducation*DZ	-0.4275**	-0.4180**	0.3165**	0.3050**
	(0.1796)	(0.1801)	(0.1336)	(0.1320)
DZ	Yes	Yes	Yes	Yes
ΔBirth weight	No	Yes	No	Yes
ΔBirth weight*DZ	No	Yes	No	Yes
Twin pairs	426	426	367	367
Observations	852	852	734	734
R^2	0.02	0.02	0.10	0.10

Notes: Here Δ is a within-twin difference operator. Δ*Education* is the difference between the self-reported schooling years for twin 1 and self-reported schooling years for twin 2. Robust standard errors are in parentheses. * Significant at the 10% level. ** Significant at the 5% level. *** Significant at the 1% level.

TABLE 5
Endowments and Spousal Age

	Dependent variable: ΔSpousal age							
	Men	Men	Men	Men	Women	Women	Women	Women
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ΔEducation	0.0570	0.0609	-0.0190	-0.0129	0.1062	0.1158	0.0450	0.0540
	(0.0827)	(0.0834)	(0.0740)	(0.0739)	(0.0868)	(0.0880)	(0.0936)	(0.0951)
ΔEducation*DZ	-0.3869***	-0.3907***	-0.2408**	-0.2469**	0.2331*	0.2224*	0.2259	0.2169
	(0.1282)	(0.1276)	(0.1200)	(0.1183)	(0.1321)	(0.1333)	(0.1502)	(0.1513)
DZ	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ΔBirth weight	No	Yes	No	Yes	No	Yes	No	Yes
ΔBirth weight*DZ	No	Yes	No	Yes	No	Yes	No	Yes
ΔAge at first marriage	No	No	Yes	Yes	No	No	Yes	Yes
ΔAge at first marriage*DZ	No	No	Yes	Yes	No	No	Yes	Yes
Twin pairs	426	426	426	426	404	404	404	404
Observations	852	852	852	852	808	808	808	808
R^2	0.02	0.03	0.16	0.17	0.02	0.03	0.05	0.05

Notes: Here Δ is a within-twin difference operator. Δ*Education* is the difference between the self-reported schooling years for twin 1 and self-reported schooling years for twin 2. Robust standard errors are in parentheses. * Significant at the 10% level. ** Significant at the 5% level. *** Significant at the 1% level.

TABLE 6
Endowments and Spousal Height

	Dependent variable: ΔSpousal height							
	Men	Men	Men	Men	Women	Women	Women	Women
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ΔEducation	0.0819	0.0878	0.0889	0.0935	0.1924	0.1821	0.1832	0.1714
	(0.1670)	(0.1672)	(0.1672)	(0.1672)	(0.1926)	(0.1945)	(0.1954)	(0.1974)
ΔEducation*DZ	0.6112**	0.6053**	0.5850**	0.5803**	-0.2042	-0.1934	-0.0815	-0.0694
	(0.2464)	(0.2482)	(0.2495)	(0.2510)	(0.2977)	(0.2984)	(0.3216)	(0.3249
DZ	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ΔOwn height	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ΔOwn height*DZ	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ΔBirth weight	No	Yes	No	Yes	No	Yes	No	Yes
ΔBirth weight*DZ	No	Yes	No	Yes	No	Yes	No	Yes
ΔAge at first marriage	No	No	Yes	Yes	No	No	Yes	Yes
ΔAge at first marriage*DZ	No	No	Yes	Yes	No	No	Yes	Yes
Twin pairs	426	426	426	426	404	404	404	404
Observations	852	852	852	852	808	808	808	808
R^2	0.04	0.04	0.04	0.04	0.02	0.02	0.02	0.02

Notes: Here Δ is a within-twin difference operator. Δ*Education* is the difference between the self-reported schooling years for twin 1 and self-reported schooling years for twin 2. Robust standard errors are in parentheses. * Significant at the 10% level. ** Significant at the 5% level. *** Significant at the 1% level.

TABLE 7
Endowments and Spousal Education

	Dependent variable: ΔSpousal education							
	Men	Men	Men	Men	Women	Women	Women	Women
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ΔEducation	0.2350***	0.2331***	0.2194***	0.2184***	0.2397**	0.2412**	0.2523**	0.2543**
	(0.0721)	(0.0726)	(0.0732)	(0.0737)	(0.1024)	(0.1042)	(0.1053)	(0.1074)
ΔEducation*DZ	-0.0519	-0.0500	-0.0294	-0.0284	0.3814***	0.3786**	0.3392**	0.3373**
	(0.1426)	(0.1431)	(0.1446)	(0.1451)	(0.1462)	(0.1477)	(0.1529)	(0.1545)
DZ	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ΔBirth weight	No	Yes	No	Yes	No	Yes	No	Yes
ΔBirth weight*DZ	No	Yes	No	Yes	No	Yes	No	Yes
ΔAge at first marriage	No	No	Yes	Yes	No	No	Yes	Yes
ΔAge at first marriage*DZ	No	No	Yes	Yes	No	No	Yes	Yes
Twin pairs	426	426	426	426	404	404	404	404
Observations	852	852	852	852	808	808	808	808
R^2	0.03	0.03	0.03	0.03	0.10	0.10	0.10	0.11

Notes: Here Δ is a within-twin difference operator. Δ*Education* is the difference between the self-reported schooling years for twin 1 and self-reported schooling years for twin 2. Robust standard errors are in parentheses. * Significant at the 10% level. ** Significant at the 5% level. *** Significant at the 1% level.

TABLE 8
Endowments and Spousal Wage at Marriage

	Dependent variable: Δ Log spousal wage							
	Men	Men	Men	Men	Women	Women	Women	Women
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ΔEducation	0.0446	0.0462	0.0604	0.0611	0.0495**	0.0491**	0.0484**	0.0480**
	(0.0397)	(0.0401)	(0.0403)	(0.0406)	(0.0222)	(0.0221)	(0.0232)	(0.0230)
ΔEducation*DZ	-0.0094	-0.0109	-0.0239	-0.0246	0.0731**	0.0730**	0.0839**	0.0845**
	(0.0896)	(0.0900)	(0.0883)	(0.0887)	(0.0299)	(0.0299)	(0.0347)	(0.0346)
DZ	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ΔBirth weight	No	Yes	No	Yes	No	Yes	No	Yes
ΔBirth weight*DZ	No	Yes	No	Yes	No	Yes	No	Yes
ΔAge at first marriage	No	No	Yes	Yes	No	No	Yes	Yes
ΔAge at first marriage*DZ	No	No	Yes	Yes	No	No	Yes	Yes
Twin pairs	426	426	426	426	404	404	404	404
Observations	852	852	852	852	808	808	808	808
R^2	0.01	0.01	0.01	0.01	0.07	0.07	0.07	0.07

Notes: Here Δ is a within-twin difference operator. Δ*Education* is the difference between the self-reported schooling years for twin 1 and self-reported schooling years for twin 2. Robust standard errors are in parentheses. * Significant at the 10% level. ** Significant at the 5% level. *** Significant at the 1% level.