Why Does Spousal Education Matter for Earnings? Assortative Mating and Cross-Productivity

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Spousal education is correlated with earnings for two reasons: cross-productivity between couples and assortative mating. This article empirically disentangles the two effects by using Chinese twins data. We have two innovations: using twins data to control for the unobserved mating effect in our estimations and estimating both current and wedding-time earnings equations. We find that both cross-productivity and mating are important in explaining the current earnings. Although the mating effect exists for both husbands and wives, the cross-productivity effect mainly runs from Chinese husbands to wives. Our findings shed light on the theories of human capital, marriage, and the family.

I. Introduction

In the human capital literature, economists have focused on an individual's formal schooling (Heckman and Polachek 1974; Mincer 1974;

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Becker 1993; Ashenfelter and Krueger 1994; Behrman, Rosenzweig, and Taubman 1994; Card 1999). Two issues of particular interest to economists are investment in education and the return to education. Although formal education is an important way to obtain human capital, it can be accumulated in many different ways. Military service (De Tray 1982), training programs (Heckman, Lalonde, and Smith 1999), learning by doing (Foster and Rosenzweig 1995), and learning from family members (Behrman, Rosenzweig, and Vashishtha 1999) and neighbors (Foster and Rosenzweig 1995) can all help a person accumulate human capital, although very little is known about how much these alternative learning channels can contribute.

This article studies a very unique channel of human capital accumulation: learning from a spouse. Economists have long noticed the positive relationship between spousal education and a person's own earnings (Benham 1974; Neuman and Ziderman 1992; Tiefenthaler 1997). Two major hypotheses have been put forward to interpret this positive correlation. First, the cross-productivity hypothesis maintains that spousal education helps an individual accumulate human capital and increase earnings: for example, couples can share ideas within the family, which is considered to be productive (see, e.g., Benham 1974; Scully 1979; Kenny 1983; Wong 1986; Lam and Schoeni 1993; Lefgren and McIntyre 2006). Second, the observed correlation may simply be a consequence of the assortative mating effect in the marriage market; that is, those who marry well-educated people are of higher ability (Welch 1974; Liu and Zhang 1999; Lefgren and McIntyre 2006). According to Becker (1973, 1974), both hypotheses can, in theory, be correct. In econometric language, the cross-productivity effect is the causal effect of spousal education on earnings, but the mating effect is caused by omitted variables. An ordinary least squares (OLS) estimate of the effect of spousal education on earnings may not show the causal effect because spousal education is likely to pick up one's own ability or the mating effect (Boulier and Rosenzweig 1984).

We will attempt to distinguish empirically between cross-productivity and the mating effect by employing unique data on twins that we recently collected from urban China. There are two major innovations in our design of the tests and the data collection method. The first is the use of the data on twins to control for omitted variable bias, or the mating effect, in our estimations. Since monozygotic (MZ; from the same egg) twins possess identical genes and family background, their unobservable abilities and backgrounds are also very similar. Hence, within-twin difference would

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largely remove the bias caused by the assortative mating effect with respect to unobservable abilities or family background.[1] However, within-twin estimations may not completely remove all of the omitted abilities (or the mating effect) because these abilities may not be fully explained by genes or family background. Our second innovation tackles this issue. In our survey, we collected information on individuals' earnings and other variables at the time of marriage, and we estimate a wedding-time earnings equation. By comparing the estimated effects of current earnings and wedding-time earnings, we can distinguish the cross-productivity effect from the mating effect. Because the cross-productivity effect takes time to be realized, it is relatively unimportant at the time of the wedding. Any effect of spousal education on wedding-time earnings, therefore, would be more likely to stem from the mating effect.

The empirical results suggest the existence of the mating effect for both females and males, but there is strong evidence of cross-productivity effect only from husbands to wives. The magnitude of a cross-productivity effect is large: an additional year of a husband's schooling increases the wife's earnings by 3.3%. Our results are robust when we control for the measurement error in own education. We also find that the husband's education increases his wife's earnings by raising her hourly wage rate rather than her work hours.

Our findings that spousal education has a cross-productivity effect shed light on our understanding of the theories of human capital, marriage, and the family. Recently, there have been advances in the empirical literature of human capital that use novel methods to control for unobservables and to measure the causal effect of human capital on earnings and on intergenerational transfer. However, this literature has focused either on an individual's own human capital (see, e.g., Ashenfelter and Krueger 1994; Isacsson 1999, 2004, 2007) or on parental human capital (see, e.g., Behrman and Rosenzweig 2002; Plug 2004). As far as we know, few studies have attempted to measure the causal effect of spousal education on earnings. Our findings suggest that marriage may improve an individual's human capital through learning within marriage. This is true for Chinese wives. People can accumulate human capital not only through formal education or by having well-educated parents but also by having a well-educated spouse. This suggests that we should rethink the process of human capital accumulation and, in particular, that we should pay more attention to channels other than an individual's own schooling. Formal schooling is certainly an important way to acquire human capital, but it is not the only way.

Our study builds upon prior literature that explicitly examines the

[1] See Ashenfelter and Krueger (1994), Behrman and Rosenzweig (1999), and Isacsson (1999, 2007) for recent studies using the twins strategy.

existence of cross-productivity or/and the mating effect. The most closely related paper is Lefgren and McIntyre (2006), which shows that women's education has both a cross-productivity effect and a mating effect.[2] However, Lefgren and McIntyre do not examine the association between men's education and wives' income. They are also not satisfied with their instrumental variables used in the estimations. Our article differs from the prior literature in that we identify both the mating effect and the cross-productivity effect by using the twins strategy to control for the unobserved mating effect and by estimating both current and wedding-time earnings equations.

This article is organized as follows. Section II introduces the methods of estimation that draw on twins data. Section III describes the survey and the data. Section IV reports the empirical results. Section V concludes the article.

II. Empirical Strategies

Our empirical work begins with estimating the log current earnings equation, given as

$$y_i^c = X_i\alpha + \beta \text{sedu}_i + Z_i\gamma + \mu_i + \varepsilon_i, \qquad (1)$$

where the subscript i refers to individual i; y_i^c is the logarithm of current earnings; sedu_i is individual i's spousal education; X_i is the set of observed family variables; Z_i is a set of observed individual variables that affect earnings, including one's own education, age, and gender; μ_i represents unobservable variables that also affect earnings, that is, the effect of ability or family background; and ε_i is the disturbance term, which is assumed to be independent of Z_i and μ_i.

The OLS estimate of β in equation (1) might be regarded as the cross-productivity effect if we can control for the assortative mating effect by Z_i and μ_i. Such an estimate of the cross-productivity effect β is generally biased because we normally cannot perfectly measure μ_i, which may be correlated with sedu_i. This bias can also be called the assortative mating in education: that is, matching one's ability or family background with spousal education such that more able people are both likely to get higher earnings and tend to marry better-educated partners; without controlling for μ_i, β is still a combination of both the cross-productivity effect and the assortative mating effect, where the latter is the bias in the estimation of the pure cross-productivity effect.

[2] A somewhat related paper by Lam and Schoeni (1993) finds that the education of fathers-in-law is more important than parental education in explaining earnings, which suggests a mating effect. However, they do not directly study the impact of spousal education.

A. The Twins Strategy

One approach to control for the mating effect is to apply the fixed effects model to twins samples. As monozygotic twins are genetically identical and have the same family backgrounds, they should have the same μ_i. Taking the within-twins difference eliminates the ability and family effect μ_i and separates the unobserved mating effect from the causal cross-productivity effect. Intuitively, by contrasting the earnings of identical twins with different spousal education, we could ensure that the correlation we observe between spousal education and one's earnings is not due to a correlation between spousal education and one's genes or family background.

The fixed effects model can be specified as follows. The current earnings equations of a pair of twins are given as

$$y_{1i}^{c} = X_i\alpha + \beta \mathrm{sedu}_{1i} + Z_{1i}\gamma + \mu_i + \varepsilon_{1i}, \tag{2}$$

$$y_{2i}^{c} = X_i\alpha + \beta \mathrm{sedu}_{2i} + Z_{2i}\gamma + \mu_i + \varepsilon_{2i}, \tag{3}$$

where y_{ji}^{c} $(j = 1, 2)$ is the logarithm of the current earnings of the first and second twins in the pair; X_i is the set of observed variables that vary by family but not between the twins, that is, the family background variables; sedu_{ji} $(j = 1, 2)$ is the spousal education for twin j in family i; and Z_{ji} $(j = 1, 2)$ is a set of variables that varies between the twins.

A within-twins or fixed effects estimator of β for identical twins, β_{FE}, is based on the first-difference of equations (2) and (3):

$$y_{1i}^{c} - y_{2i}^{c} = \beta(\mathrm{sedu}_{1i} - \mathrm{sedu}_{2i}) + (Z_{1i} - Z_{2i})\gamma + (\varepsilon_{1i} - \varepsilon_{2i}). \tag{4}$$

The first difference removes both the observable and unobservable family effects, that is, X_i and μ_i. As μ_i is removed, we can apply the OLS method to equation (4) without worrying about bias caused by the omitted gene and family background variables.

B. Remaining Biases

Bound and Solon (1999) have examined the implications of the endogenous determination of which twin receives more formal education, and they conclude that twins-based estimation is vulnerable to the same sort of bias affecting conventional cross-sectional estimation. The resultant major concern of the within-twins estimate is whether it is less biased than the OLS estimate and therefore a better estimate (Bound and Solon 1999; Neumark 1999). From this work we can argue that, although the within-twins differencing removes genetic variation, that is, it removes μ_i from equation (4), this difference may still reflect an ability bias because ability consists of more than just genes. In other words, within-twins estimation may not completely eliminate the bias of conventional cross-sectional estimation because the within-twins difference in ability may remain in $\varepsilon_{1i} - \varepsilon_{2i}$ in equation (4), which may be correlated with $\text{sedu}_{1i} - \text{sedu}_{2i}$. If endogenous variation in spousal education comprises as large a proportion of the remaining within-twins variation as it does of the cross-sectional variation, then within-twins estimation is subject to as large an endogeneity bias as cross-sectional estimation.

Although within-twins estimation cannot completely eliminate the bias of the OLS estimator, it may tighten the upper bound on the return to spousal education.[3] Ashenfelter and Rouse (1998), Bound and Solon (1999), Neumark (1999), and Isacsson (2007) have debated the bias with OLS and within-twins estimation at length. Note that the bias in the OLS estimator depends on the fraction of variance in spousal education accounted for by variance in unobserved ability that may also affect earnings; that is, $\text{Cov}(\text{sedu}_i, \mu_i + \varepsilon_i)/\text{Var}(\text{sedu}_i)$. Similarly, the bias of the fixed effects estimator depends on the fraction of within-twins variance in spousal education accounted for by within-twins variance in unobserved ability also affecting earnings, that is, $\text{Cov}(\Delta\text{sedu}_i, \Delta\mu_i + \Delta\varepsilon_i)/\text{Var}(\Delta\text{sedu}_i)$. If we are confident that spousal education and the earnings error term are positively correlated both in the cross-sectional and within-twins regressions, and if the endogenous variation within a family is smaller than the endogenous variation between families, then the fixed effects estimator is less biased than the OLS estimator. Hence, even if there is an ability bias in the within-twins regressions, the fixed effects estimator can still be regarded as an upper bound on the return to spousal education (if spousal education and ability are positively correlated); in that case, we can credit the within-twins estimates with having tightened the upper bound on the return to spousal education.

C. Wedding-Time Earnings

The prior subsection demonstrates that we are concerned that the within-twins estimations may not completely remove all the mating effects and that the estimated coefficient of spousal education on current earnings may still consist of both a cross-productivity effect and a mating effect. Generally, it is very difficult to completely disentangle the two effects empirically.

Another innovation of our article is to establish an upper bound for the omitted mating effect by estimating a wedding-time earnings equation. As couples have fewer opportunities to help each other accumulate human capital before marriage, the cross-productivity effect should be relatively unimportant at this time. The within-twins estimate of the effect of spousal education on wedding-time earnings can therefore establish an upper bound for the omitted mating effect in such a model.

[3] This is true only when the measurement error problem is not very severe.

The specific wedding-time earnings equations of a pair of twins are given as

$$y_{1i}^m = X_i\alpha^m + \beta^m \text{sedu}_{1i} + Z_{1i}\gamma^m + \mu_i + v_{1i}, \tag{5}$$

$$y_{2i}^m = X_i\alpha^m + \beta^m \text{sedu}_{2i} + Z_{2i}\gamma^m + \mu_i + v_{2i}, \tag{6}$$

where y_{ji}^m $(j = 1, 2)$ is the logarithm of the wedding-time earnings of the first and second twin in the pair. A within-twins estimator for identical twins is based on the first difference of equations (5) and (6):

$$y_{1i}^m - y_{2i}^m = \beta^m(\text{sedu}_{1i} - \text{sedu}_{2i}) + (Z_{1i} - Z_{2i})\gamma^m + (v_{1i} - v_{2i}). \tag{7}$$

The within-twins estimate of β^m consists of both the cross-productivity effect and the remaining mating effect if mating is individual specific (rather than family specific). However, as cross-productivity is relatively unimportant at the time of the wedding, the estimated β^m establishes an upper bound for the remaining mating effect that is not controlled for by the within-twins estimations. If our within-twins model can fully control for the mating effect, then the estimated β^m should be close to zero.

III. Data

The data we use are derived from the Chinese Twins Survey (CTS), which was carried out by the Urban Survey Unit (USU) of the National Bureau of Statistics (NBS) in June and July 2002 in five cities in China. The survey was funded by the Research Grants Council of Hong Kong. Based on existing twins questionnaires in the United States and elsewhere, the survey covered a wide range of socioeconomic information. The questionnaire was designed by Junsen Zhang in close consultation with Mark Rosenzweig and Chinese experts from the NBS. Adult twins ages 18–65 years were identified by the local statistical bureaus through various channels, including colleagues, friends, relatives, newspaper advertisements, neighborhood notices, neighborhood management committees, and household records from the local public security bureau. Overall, these channels permitted a roughly equal probability of contacting all of the twins in these cities; hence, the twins sample obtained is approximately representative. (The within-twins estimation method used for this study controls for the first-order effects of any unobserved characteristics that may have led to the selection of twins pairs in the sample.) The questionnaires were completed through household face-to-face personal interviews. The survey was conducted with considerable care, and several site checks were made by Junsen Zhang and experts from the NBS. Following appropriate discussion with Mark Rosenzweig and other experts, the data input process was closely supervised and monitored by Junsen Zhang himself in July and August 2002.

This is the first socioeconomic twins data set in China and possibly the first in Asia. The data set includes rich household socioeconomic information for respondents in five cities: Chengdu, Chongqing, Haerbin, Hefei, and Wuhan. Altogether, there are 3,012 observations. We can determine whether the twins are identical (MZ) or nonidentical. We consider a pair of twins identical if both twins responded that they have identical hair color, look, and gender. Of these 3,012 individuals, we have complete information for 448 pairs of married twins (896 individuals),[4] of which 274 pairs are identical twins (548 individuals).

There are a few unique survey designs for this study. First, we collected detailed information on the twins' spouses, in particular on their years of schooling. Second, we collected information on current earnings (at the time of the survey, 2002) and the wedding-time earnings. Third, we collected information on current working hours, which allowed us to calculate the current hourly wage rate. We also tried to ask retrospective questions on the wedding-time working hours in our pretest, but we found that most only remembered their monthly earnings and not the working hours. Thus, we only asked for the wedding-time monthly earnings and not for working time in the formal survey. As far as we know, our survey has been the first to ask for this additional information, which helps us disentangle the mating effect from the cross-productivity effect of spousal earnings.

We define variables according to the literature. The descriptive statistics are reported in table 1. In column 1, we report the mean of all variables for identical twins. Fifty-three percent of these identical twins are male. On average, they were 40 years old, had 12 years of schooling, and their spouses also had an average of 12 years of schooling. They had monthly earnings of 906 yuan in 2002, where earnings include wages, bonuses, and subsidies. They had also been earning 346 yuan (normalized to 2002 yuan) when they got married. On average, they worked 171 hours a month in 2002, with an hourly wage rate of 5.66 yuan. In columns 2 and 3 of table 1, we report descriptive statistics for male MZ twins and female MZ twins, respectively. In our sample, there are 146 pairs of male MZ twins and 128 pairs of female MZ twins. On average, males earn more than females do in terms of both monthly earnings and hourly wage rate in 2002; while females' years of schooling are slightly above males' in our sample, the females' husbands are more educated than they are within the families.

[4] The divorce rate is low in China. In our sample, only 3% of individuals have ever become divorced, and they are not included in our analysis.

Table 1
Descriptive Statistics of the MZ Twins Sample

Variable	Full Sample (1)	Male (2)	Female (3)
Gender (male = 1, female = 0)	.53		
	(.50)		
Age	40.09	41.18	38.85
	(7.73)	(7.63)	(7.67)
Own education (years of schooling)	11.90	11.60	12.24
	(3.08)	(3.16)	(2.95)
Current earnings (monthly wage, bonus, and subsidy in 2002 yuan)	905.94	998.42	800.45
	(522.90)	(583.86)	(420.17)
Current hourly wage rate	5.66	6.15	5.10
	(3.74)	(4.04)	(3.28)
Current monthly work hours	170.96	174.73	166.67
	(44.63)	(43.70)	(45.38)
Wedding-time earnings (monthly wage, bonus, and subsidy in 2002 yuan)	346.37	364.65	325.51
	(344.05)	(384.70)	(290.17)
Spousal education (years of schooling)	11.55	10.83	12.37
	(3.08)	(3.09)	(2.94)
Labor force participation	.930	.926	.934
Sample size	548	292	256

NOTE.—The numbers in parentheses are standard deviations.

IV. Empirical Results

In this section, we report the estimated effect of spousal education by using different samples and methods. We start with OLS regressions and then report within-twins fixed effects estimates. All regression models are applied to female and male twins samples separately for reasons we discuss next.

A. Difference between Sexes

There are reasons to believe that the role of cross-productivity is different for husbands and wives within a family. The two sexes may have different learning abilities and, more importantly, one may be more dominant than the other.[5] For example, if the husband dominates in a family and makes job and other decisions for the wife, then one may expect the husband's education to be important in determining the wife's earnings but the wife's education to be unimportant in determining husband's earnings.

In fact, China provides an interesting social setting where one might

[5] In a sense, when one sex is dominant, it is like the family in Becker's unitary model (Becker 1991).

Table 2
OLS and Fixed Effects Estimates of the Effect of Spousal Education on Current Earnings for Male and Female Twins

	OLS				Fixed Effects			
	Female MZ Twins		Male MZ Twins		Female MZ Twins		Male MZ Twins	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Spousal education	.063***	.026**	.083***	.057***	.035**	.034**	.031	.029
	(.011)	(.012)	(.009)	(.011)	(.014)	(.014)	(.024)	(.024)
Own education		.083***		.047***		.026		.016
		(.011)		(.011)		(.023)		(.028)
Age	.009*	.014***	.001	.003				
	(.005)	(.005)	(.004)	(.004)				
Observations	256	256	292	292	256	256	292	292
Twin pairs	128	128	146	146	128	128	146	146
R^2	.11	.26	.24	.28	.07	.09	.02	.02

NOTE.—Robust standard errors are in parentheses; all regressions control city dummy variables;
* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.

expect that males dominate in families. Although patriarchalism has become antiquated in the West, Chinese families had remained patriarchal until quite recently (Ch'u 1961; Hamilton 1990), where the father was still the head of the family and had authority over all of its members. His control of the family economy and his power to make decisions on resource allocation strengthened that authority. The concept of ancestor worship, central to the solidarity of the family and to its perpetuation, further enhanced the authority of the family head, who was also the family priest. In recent years, however, women have gained greater decision-making power in daily family affairs. According to a national survey on family life conducted by the All-China Women's Federation (*China Daily*, September 10, 2002), 57% of wives have more say than their husbands in decisions on minor, daily spending, whereas only 13.9% of husbands assume the role of decision maker in similar matters.[6] However, when it comes to major family decision making, husbands still have the upper hand, with 24.5% having the final say, whereas only 7% of wives make similar decisions. These survey results indicate that, although women's position in the family has improved, men still dominate in Chinese families.

B. OLS Estimates

In the first four columns of table 2, we report the results of OLS regressions. Columns 1 and 2 use the female twins sample, and columns 3 and 4 use the male twins sample. The dependent variable is the logarithm of monthly earnings.

[6] The remaining spouses make such decisions jointly.

In column 1, we report a regression with spousal education and age as independent variables. The regression shows that a person can get a 6.3% increase in earnings when the spousal education increases by 1 year. This effect is precisely estimated with a standard error of 0.011. Age also has a significant coefficient, with a 1% earning premium for an increment in age.

In column 2, we add one's own education as an independent variable. With this new independent variable, the coefficient on spousal education drops to 2.6%, though it remains significant at the 5% level. This drop suggests that there is a mating effect; that is, spousal education in column 1 picks up the positive effect of a woman's own human capital variable. Indeed, a woman's own human capital variable, education, has a positive and significant effect on earnings. Increasing a woman's own education by 1 year increases earnings by 8.3%.

In columns 3 and 4, we report the same OLS regressions using the male twins sample. Similarly, we find a large effect of spousal education when we do not include a man's own education (col. 3), and the effect of spousal education remains large and significant after we control for own education (col. 4). Although the effect of spousal education is generally larger for the male twins sample as compared to that for the female twins sample, the effect of a man's own education is smaller. It is also interesting to note that, although the effect of age is very large for females, that for males is small.[7]

C. Fixed Effects Estimates

Although the OLS estimates of the effect of spousal education are large for both women and men, the model cannot identify how much of this estimate is due to the cross-productivity effect and how much is due to mating, that is, the effect of unobserved ability or family background. Next, we try to distinguish between the two effects by using the twins strategy.

In columns 5–8 of table 2, we report the results of within-twins fixed effects estimations of the earnings equation, or the estimations of equation (4), for the female and male twins samples, respectively. As MZ twins have the same age, the age variable is dropped when taking the within-twins difference.

The within-twins estimates of the effect of the spousal education for female twins are close to the OLS estimates. Comparing column 6 to column 2, the coefficient for spousal education increases a little, but the difference is not significantly different from zero. In stark contrast, the coefficient for a woman's own education decreases dramatically in the within-twins estimate. For the male sample, the within-twin estimate of

[7] This seems to be in contrast to findings using U.S. data.

the spousal education (col. 8) is smaller than the OLS estimate (col. 4) and becomes insignificant. Note that overall the fixed effects estimates on spousal education for male and female samples are very close, though the standard errors are larger for the male sample.

One interesting finding is that the effect of spousal education is greater than that of one's own education in the within-twins estimate in column 6, though the reverse is true in the OLS estimate (col. 2). This happens because one's own education is more associated with one's own unobserved ability or family background than spousal education, and therefore it becomes less important once we control for the unobserved gene and family background variables.

These results imply two things. First, the mating effect is important, and it seems that including one's own education as a covariate is a good way to control for the mating effect. Second, after removing the mating effect by the within-twin differencing, there remains a positive effect of spousal education, which is very likely to be the true cross-productivity effect. We further investigate this next.

D. Instrumental Variable Fixed Effects Model to Correct Measurement Error

One primary issue that we need to deal with is the measurement error of own education in the estimate. It is well known that classical errors in the measurement of schooling lead to a downward bias in the estimate of the effect of schooling on earnings and that the fixed effects estimator magnifies such measurement error bias for own education as the educations of a pair of twins are generally very similar. More importantly for our study, the measurement error of own education could also potentially bias the coefficient of spousal education.

One way to solve the problem of measurement error bias is to use the instrumental variable (IV) method. In this study, we follow the approach used by Ashenfelter and Krueger (1994) to obtain good instrumental variables. Specifically, in our survey we asked each twin to report both their own education and their co-twin's education. Where there is a risk of measurement error in the self-reports of education, the cross-report is a potentially good instrument as the report of the other twin should be correlated with the true educational level of a twin but uncorrelated with any measurement error that might be contained in the self-report.

Following Ashenfelter and Krueger (1994), the instrumental variable approach can be applied as follows. Writing Z_j^k for twin k's report of twin j's schooling and assuming classical measurement error, we use $Z_1^1 - Z_2^2$ as the regressor and $Z_1^2 - Z_2^1$ as the instrumental variable in differenced equation (4). The identification assumption for this IV method is that the measurement error terms in $Z_1^1 - Z_2^2$ and $Z_1^2 - Z_2^1$ are uncorrelated. Note

Table 3
Instrumental Variable Fixed Effects Estimates of the Effect of Spousal Education on Current Earnings for Male and Female Twins

	Female MZ Twins		Male MZ Twins	
Sample	IVFE-1 (1)	IVFE-2 (2)	IVFE-1 (3)	IVFE-2 (4)
Spousal education	.033**	.033**	.027	.027
	(.015)	(.015)	(.024)	(.024)
Own education ($\Delta Z'$ or $\Delta Z^{\dagger}$)	.041	.039	.026	.029
	(.033)	(.029)	(.030)	(.032)
Observations	256	256	292	292
Twin pairs	128	128	146	146

Note.—The dependent variable is log(current earnings). Here $\Delta Z'$ is the difference between the self-reported education of twin 1 and the self-reported education of twin 2; $\Delta Z''$ is the difference between the education of twin 1 reported by twin 2 and the education of twin 2 reported by twin 1; $\Delta Z^{\dagger}$ ($\Delta Z^{\ddagger}$) is the difference between twin 1's (twin 2's) report of his or her own education and his or her (twin 2's) report of the other twin's education. In the model of IVFE-1, $\Delta Z'$ is the regressor and $\Delta Z''$ is the instrumental variable; in the model of IVFE-2, $\Delta Z^{\dagger}$ is the regressor and $\Delta Z^{\ddagger}$ is the instrumental variable. Robust standard errors are in parentheses; all regressions control city dummy variables.
** Significant at the 5% level.

that this approach is valid even in the presence of common family-specific measurement errors because the family effect is eliminated through differencing. We call this instrumental variable model the IVFE-1.

Before reporting the IV estimates, it is worth examining the correlations between the education variables. The correlations between the self and co-twin reports of the education of the same twin, or $\mathrm{Cov}(Z_1^1, Z_1^2)$ and $\mathrm{Cov}(Z_2^2, Z_2^1)$, are 0.903 and 0.966 in our sample, as compared to 0.920 and 0.877 in the sample of Ashenfelter and Krueger (1994). These high correlations suggest that the extent of the measurement error here is less than that in their paper, as these correlations are estimates of the reliability ratio of the education measures. The high correlations also suggest that the co-twin-reported level of education is a good instrumental variable for the self-reported level of education in our sample.

However, the IVFE-1 estimates may also be biased if the measurement error terms in $Z_1^1 - Z_2^2$ and $Z_1^2 - Z_2^1$ are correlated. This occurs if there is an individual-specific component of the measurement error in reporting education. One typical example would be that a twin overreports her own education as well as the education for her twin sister. This motivates us to implement another instrumental variable that will be valid even in the presence of correlated measurement errors (Ashenfelter and Krueger 1994). To eliminate the individual-specific component of the measurement error in the estimation, it is sufficient to use $Z_1^1 - Z_2^1$ as the regressor in equation (4) and $Z_1^2 - Z_2^2$ as the IV. We call this estimator IVFE-2.

The IVFE estimates reported in table 3 show that measurement error has biased the fixed effects estimates of own education in columns 5–8 of table 2 downward, as in other studies in the literature. The IVFE estimates of the return to own education rise, though they remain insignificant. Most importantly, when correcting the measurement error of own education, the effect of spousal education for both females and males only changes slightly, suggesting that measurement error is not a major concern for the estimates of the effect of spousal education. In particular, the effect of husband's education on wife's earnings remains large and significant. Although the estimate of the wife's education on the husband's earnings is insignificant, one cannot reject that it is equal to the effect of husband's education on wife's earnings.

Both IVFE methods rely on the general assumption that the error term in the differenced independent variable is uncorrelated with the error term in the differenced instrument. Under certain conditions, if the two error terms are correlated, then both methods become invalid. For example, when twin 1 mistakenly thinks herself more educated, twin 2 also mistakenly thinks twin 1 is more educated. In this case, the error term in Z_1^1 and that in Z_1^2 are correlated and cannot be canceled by within-twin differencing, making both identification methods fail.

Our empirical results seem to suggest that this general identifying assumption is met. Table 3 shows that, although the estimated coefficient on own education is biased in the FE model, that on spousal education does not appear to be biased. The IVFE results for log earnings on spouse education (table 3) are almost identical to the FE results from table 2. These results increase our confidence in the instruments. The fact that the spousal education coefficient is impervious to the use of the IV method suggests that spousal education may not be too contaminated by mismeasured education.

E. Wedding-Time Earnings

As the within-twins estimations may not completely remove all the mating effects, the estimated coefficient on spousal education on current earnings may still consist of both the cross-productivity effect and the remaining mating effect. To disentangle the cross-productivity effect from the mating effect, we establish an upper bound for the omitted mating effect by estimating the wedding-time earnings equation.

The estimation results of the wedding-time earnings equation suggest that our econometric specification can control for the whole mating effect. In table 4, we report the IVFE estimates of the wedding-time earnings equation for female and male twins samples, respectively.[8] Note that spou-

[8] The standard error for men's own education is quite close to that for women's, though the coefficient for men is very close to zero. Note that the dependent variable is wedding-time earnings, and thus it is not surprising to see that own education has no effect when ability is controlled for in within-twin estimation. In the literature, it has been found that, before economic reform, wages were

Table 4
Instrumental Variable Fixed Effects Estimates of the Effect of Spousal Education on Wedding-Time Earnings for Male and Female Twins

	Female MZ Twins		Male MZ Twins	
Sample	IVFE-1 (1)	IVFE-2 (2)	IVFE-1 (3)	IVFE-2 (4)
Spousal education	−.002	−.002	.008	.008
	(.012)	(.012)	(.028)	(.028)
Own education ($\Delta Z'$ or $\Delta Z^{\dagger}$)	.104***	.114***	−.010	−.008
	(.032)	(.032)	(.043)	(.045)
Observations	256	256	292	292
Twin pairs	128	128	146	146

Note.—The dependent variable is log(wedding-time earnings). Here $\Delta Z'$ is the difference between the self-reported education of twin 1 and the self-reported education of twin 2; $\Delta Z''$ is the difference between the education of twin 1 reported by twin 2 and the education of twin 2 reported by twin 1; $\Delta Z^{\dagger}$ ($\Delta Z^{\ddagger}$) is the difference between twin 1's (twin 2's) report of his or her own education and his or her (twin 2's) report of the other twin's education. In the model of IVFE-1, $\Delta Z'$ is the regressor and $\Delta Z''$ is the instrumental variable; in the model of IVFE-2, $\Delta Z^{\dagger}$ is the regressor and $\Delta Z^{\ddagger}$ is the instrumental variable. Robust standard errors are in parentheses; all regressions control city dummy variables.
*** Significant at the 1% level.

sal education has almost a zero effect on one's own earnings for both female and male twins. The fact that spousal education has no effect on wedding-time earnings suggests that the whole mating effect can be well controlled for by the IVFE model.

The different results for the current and wedding-time earnings equations can be used to infer whether there is a cross-productivity effect. The estimate of the wedding-time earnings equation suggests that the mating effect can be well controlled for by our within-twins model. If we assume that the mating effect of spousal education in the current earnings equation can be fully controlled for, just as it can be in the wedding-time earnings equation, then the significant coefficient for spousal education in the current earnings equation means that there is a positive cross-productivity effect. As has been shown by tables 2 and 3, although the husband's education has a significant positive effect on his wife's current earnings, it has a zero effect on his wife's wedding-time earnings. Therefore, the cross-productivity effect of spousal education from Chinese husbands to their wives, in terms of the latter's current earnings, is approximately 3.3% per year of husbands' schooling.

F. Longer Hours or Better Paid?

In the above analysis, we use monthly earnings as our dependent variable. Spousal education may have an effect on monthly earnings through

highly compressed, and thus own education had little effect on own earnings for men at that time in China. That own education affects own wedding-time earnings for women but not for men may be due to the Chinese culture, where ability is the more important consideration for men.

Table 5
Instrumental Variable Fixed Effects Estimates of the Effect of Spousal Education on Current Hourly Wage Rate and Monthly Work Hours for Male and Female Twins

	Dependent Variable							
	Log (Female Hourly Wage Rate)		Log (Male Hourly Wage Rate)		Female Work Hours		Male Work Hours	
	IVFE-1 (1)	IVFE-2 (2)	IVFE-1 (3)	IVFE-2 (4)	IVFE-1 (5)	IVFE-2 (6)	IVFE-1 (7)	IVFE-2 (8)
Spousal education	.036**	.036**	−.008	−.009	−.816	−.818	3.934	3.990
	(.017)	(.017)	(.027)	(.026)	(1.553)	(1.569)	(2.589)	(2.579)
Own education ($\Delta Z'$ or $\Delta Z^{\dagger}$)	.014	.016	.006	.012	3.566	3.562	2.292	2.049
	(.038)	(.034)	(.031)	(.033)	(3.978)	(4.391)	(2.127)	(2.200)
Constant								
Observations	232	232	276	276	232	232	276	276
Twin pairs	116	116	138	138	116	116	138	138

NOTE.—Here $\Delta Z'$ is the difference between the self-reported education of twin 1 and the self-reported education of twin 2; $\Delta Z''$ is the difference between the education of twin 1 reported by twin 2 and the education of twin 2 reported by twin 1; $\Delta Z^{\dagger}$ ($\Delta Z^{\ddagger}$) is the difference between twin 1's (twin 2's) report of his or her own education and his or her (twin 2's) report of the other twin's education. In the model of IVFE-1, $\Delta Z'$ is the regressor and $\Delta Z''$ is the instrumental variable; in the model of IVFE-2, $\Delta Z^{\dagger}$ is the regressor and $\Delta Z^{\ddagger}$ is the instrumental variable. Robust standard errors are in parentheses.
** Significant at the 5% level.

either hourly wage rate or monthly working hours. To differentiate between the two channels, we examine the effects of spousal education on one's current hourly wage and monthly working hours. We continue to use the instrumental variable fixed effect model to control for unobserved mating effect and measurement error.

The regression results again show that the wife's education has no effect on the hourly wage rate of her husband, while the husband's education has a positive effect on the hourly wage rate of his wife. In columns 1 and 2 of table 5, the IVFE estimations show that spousal education has a significant effect on the wife's hourly wage. However, the effect of spousal education on the husband's hourly wage is essentially zero (cols. 3 and 4). For work hours of both females and males (cols. 5–8), none of the coefficients on spousal education is significant at the 10% level, though those for male work hours are relatively big and borderline significant.

In summary, these empirical results suggest that, consistent with those in table 5, the wife's education has no cross-productivity effect on the husband's hourly wage. In contrast, the husband's education has a cross-productivity effect on the hourly wage rate of his wife. There is some weak evidence that men with better-educated wives tend to work longer.

V. Conclusion

We empirically distinguish between the cross-productivity and mating effects by employing unique twins data we recently collected from urban China. By using a within-twins model for omitted variables, we can largely remove the bias caused by the assortative mating effect with respect to one's unobservable ability or family background. By comparing the estimated effects on current earnings and wedding-time earnings, we can establish an upper bound for the omitted mating effect. We find that our within-twins model can well control for the mating effect and that any effect of spousal education on current earnings is the cross-productivity effect.

Using our preferred model, the IVFE model, we find strong evidence of a cross-productivity effect from husband to wife: an additional year of the husband's schooling increases his wife's earnings by 3.3%. However, the cross-productivity effect from the wife to the husband is smaller, and it is not precisely estimated. Our finding is consistent with male dominance in Chinese society. Finally, by estimating both the hourly wage and monthly working hours equations, we find that the cross-productivity effect of husbands on wives operates by increasing the hourly wage of wives.

Spousal education may also affect earnings if a more educated person induces the spouse to exert more effort in working. If this incentive effect happens before marriage, then the wedding-time earnings may also contain the cross-productivity effect. However, this is not a major concern for us as the estimates of spousal education on wedding-time earnings are close to zero. Thus, such an incentive effect, if it exists, must happen after marriage or be a part of the cross-productivity effect that is not from learning.

The finding that spousal education has a cross-productivity effect could shed light on our understanding of the theories of human capital, marriage, and the family. Previous empirical work has shown that people can acquire earnings-enhancing human capital through formal schooling and intergenerational transfer, but it has generally paid less attention to the further improvement of human capital after formal education. In this article, we find at least one potential channel of postschool human capital acquisition, that is, learning within marriage. This has two implications. First, higher education not only improves one's own earnings and household production but also raises the earnings of one's spouse. If we only considered the effect on own earnings, we would miss an important part of the total effect of one's education on family earnings. Second, it seems that learning beyond normal schooling ages may deliver good payoffs both within and outside families. This implication becomes even more important in light of the continuing rise of life expectancy.

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