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Keywords: Marriage Market, Education, Gender Wage Gap.

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A Chinese puzzle: fewer, less empowered, lower paid and better educated women

Carmen Camacho* Yingya Xue†

March 29, 2021

Abstract

As from 2009 there are more Chinese women than men enrolled in college. To address this question, we propose a simple model with pre-marital education investment and endogenous marital matching where spouses split the joint revenue. We show that if women are not empowered enough, then neither men nor women obtain tertiary education. Women's education overtake can only arise if they are powerful enough within their marriage, if educated women's salary is sufficiently high and if there are enough educated men to mate. We calibrate our model using data from the Chinese Census in order to solve the Chinese puzzle, i.e. to understand how Chinese women are better educated without being sufficiently empowered. We find our first that despite the overall increase in education for both men and women, and the raise in women's salaries for all education levels, Chinese women have actually not gained power in the markets since the gender wage gap is widening for all levels of education. Second, that women's education is tightly linked to their power within the household. Indeed, the increase in women's education is not due to an increase in women's power, but on the contrary, a measure to counterbalance a striking decrease.

Keywords: Marriage Market, Education, Gender Wage Gap.
Journal of Economic Literature: D1, J12, J16

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1 Introduction

According to Confucian doctrines: "Women and crooks are unteachable" (Lei, Chen and Xiang, 1993). And yet, despite the historical and recent past preference for sons, despite the prevailing wage gap between men and women, and despite strongly rooted traditions, there are more women enrolled in college since 2009 in China. There were many barriers to this takeover, and some have obviously given in. To begin with, it is not true anymore that boys are preferred to girls. Girls are actually equally preferred to boys, even in rural China.[1] However, as for the second reason, the wage gap between men and women has been steadily increasing in time. Is it pausible that traditions had changed in ten years faster than in 5000 years? In this paper we develop a simple model to describe the Chinese marriage market and how parents take decisions regarding the education of their children. Even when the wage gap is large and traditions are tight, our paper finds that parents can increase girls education beyond boys' if women are powerful enough in their marriage.

Women have experienced severe gender discrimination for over five thousand years of civilization (Liu and Carpenter, 2005). Just as a gist, let us provide another principle of Confucian doctrines "A girl without intelligence and talent is one of integrity" (Mao and Shum, 1984). Although girls' have been receiving more education with time, changes before 2000 were slow. Liu and Carpenter (2005) show that the percentage of women enrolled in primary school raised from 28% in 1951 to 46.2% in 1990. Regarding secondary school, the rate raised from 25.6 to 41.9. An enormous bound, but smaller and slower than economic development over these four decades. Also Hannum (2005) finds that the elementary education gap gradually declines from the early reform years, finally ceasing in the mid-1990s in urban areas (see also Filmer, 2005, Hannum and Xie, 1994). Beyond secondary school, in 2009 the gender gap in college enrollment was even reversed to favor women. Figure 1 shows the evolution in time of the gender parity index of school enrollment in China for all educational levels, confirming that women are more educated than men as from 2009.[2] More precisely, girls started getting more basic education than boys in 1999, junior high education in 2005, senior high education in 2007 and undergraduate education in 2009. In 2009 for every 100 men undertaking undergraduate studies, there were 125 women. Besides, this new gap widens with time.

[1] There is a large recent literature demonstrating that boys are not significantly preferred to girls anymore. See for instance Filmer (2005), Hannum and Xie (1994), or Hannum (2005).

[2] Appendix A provides all details on the data sources and index construction.

Obviously, college enrollment parity is a necessary requirement to achieve the overall, complete parity. However, other factors are still lagging behind. As Kim (2013) explains, women lag behind men in some measures of human capital like work experience and political capital. In connection to this, and maybe as a consequence, in 2012 and despite holding the highest female labor participation rate in the world, only 8% of corporate board members and 9% of executive committee members were women (McKenzie, 2012). Besides the worldwide glass-ceiling, Chinese men and women face the complex problem of respecting traditions. As a result, the average income of a woman with a high junior diploma was in 2012 68% of the average income of men with the same education; 78% for senior high school graduates and 80% for junior college graduates. Using data from the Chinese Household Project, for 2007 and 2010, Figure 3 shows wages and the wage gap between men and women, dividing China in three large regions: East, Midland and West. Overall wages have more than doubled in all three regions in three years. Unfortunately, the wage gap has also increased.

Finally and in order to complete the picture, Figure 2 shows that people has been moving massively in the recent past leaving behind the countryside seeking for better employment opportunities. Part of the change in the education pattern can be explained in the light of this change, simply because there are more labor opportunities for educated women in cities. Second, parents in cities have more information about the wage gap existing between men and women (see the top of Figure 3) and decide to increase the education of their daughters to ensure them a better position inside their marriage. Third, the wage difference between educated and non educated women sharply increased from 2002 to 2013. Uneducated women were doubly disadvantaged in the labor market: first as women, and second, as uneducated. We believe that the skills wage gap is a third reason explaining the fast increase in the number of women in college. Note that even if all these factors could explain why the gender educational gap was closing, it cannot explain the overtake. To fully understand the overtake, one needs to consider the role of millenary traditions, for even if married women earned the same income as their husbands they could still not retain a share of it, reflecting their lack of power in the couple.

We believe that people have learnt about the job market, and that they are aware of both the wage gap between men and women, between educated and non-educated workers, and the weight of family traditions. The present paper develops a simple theoretical model of the marriage market, in which the education level determines, together with love, the spouse selection. Both men and women value love and education

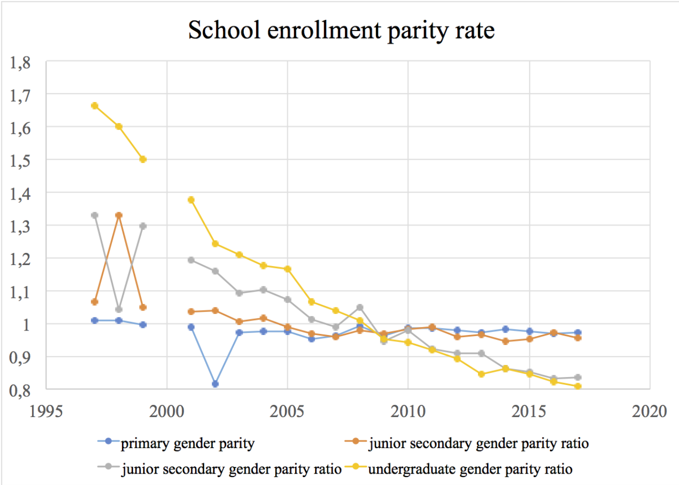

Figure 1: School enrollment gender parity index.

$$\text{GPI of school enrollment} = \frac{\text{male enrollment/male population at that age}}{\text{female enrollment/female population at that age}} \times \text{sex ratio at that age}$$

and mating is somehow random. An educated man can marry an uneducated woman if the love motive prevails. This is a partial equilibrium set-up in which education increases the unit wage. Our model also reflects the gender wage gap, and men earn more than women at all education levels. Traditions are well present in our setup. First, we translate the fact that men and women have unequal power within their marriage in the simplest manner: men and women receive a share of the common income. Suppose the share was one half, then women would always receive more than their input. However, if both partners have the same education level, and split unevenly the common income, the wife can be penalized a second time and retain less than her original salary. Second, traditions also affect the timing and nature of the marriage market: men make an opening offer and women accept it.

Obviously, we are not the first to look at this phenomenon, observed in many economies. Different reasons have been put forward. First, the most obvious reason: women increase their education if it becomes less costly. For Becker et al. (2010) it is the difference in non-cognitive skills that lessens the cost of high education for women, which take advantage to improve their future. Then, non-cognitive skills find school less difficult and they attend college more than men even if the gross benefit remains lower than for men. Charles and Luch (2003) also note that schooling is less risky for women, probably as suggested in Goldin et al. (2006), because women accumulate more

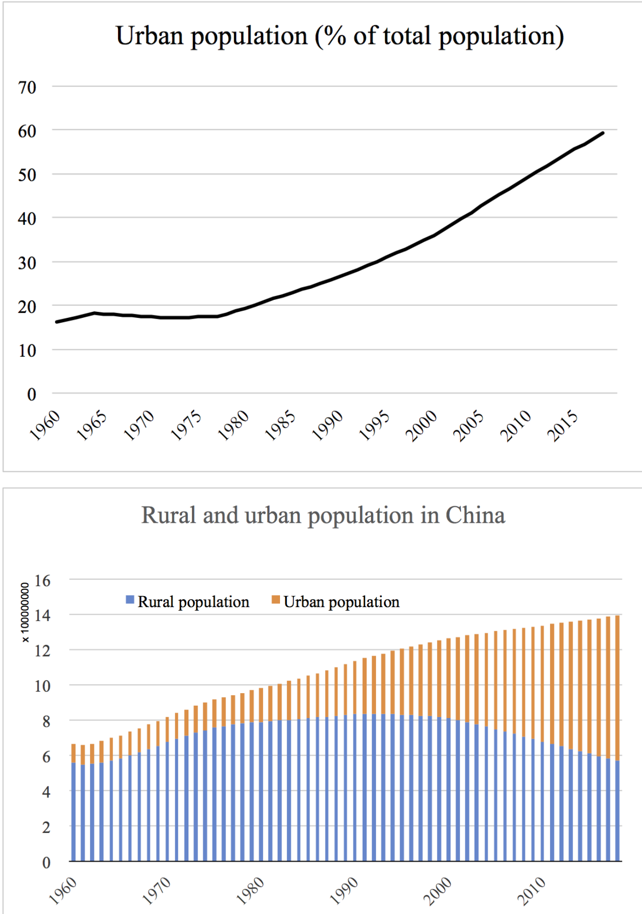

Figure 2: Rural to urban migration.

human capital than men in high school. Other factors have also been explored. For Chiappori and Weiss (2007), divorce urges further women to increase their education as an insurance against divorce costs. Within the mariage market context, Iyigun and Walsh (2007) show that if women are in competition to marry educated men, then becoming educated increases their chances to make a good marriage. Indeed, high education begets high salaries and educated men will prefer educated women to increase the expected revenue of the future couple.

Ours is a collective model of household behavior a la Chiappori (1988, 1992) where men and women meet at a large and frictionless mariage market. Following Bergstrom and Bagnoli (1993), Edlund and Korn (2002), Gould et al. (2008) and Mariani (2012), we assume that men and women search for different qualities in their future spouses, namely love, education and future joint income. Among the paper's findings, we show

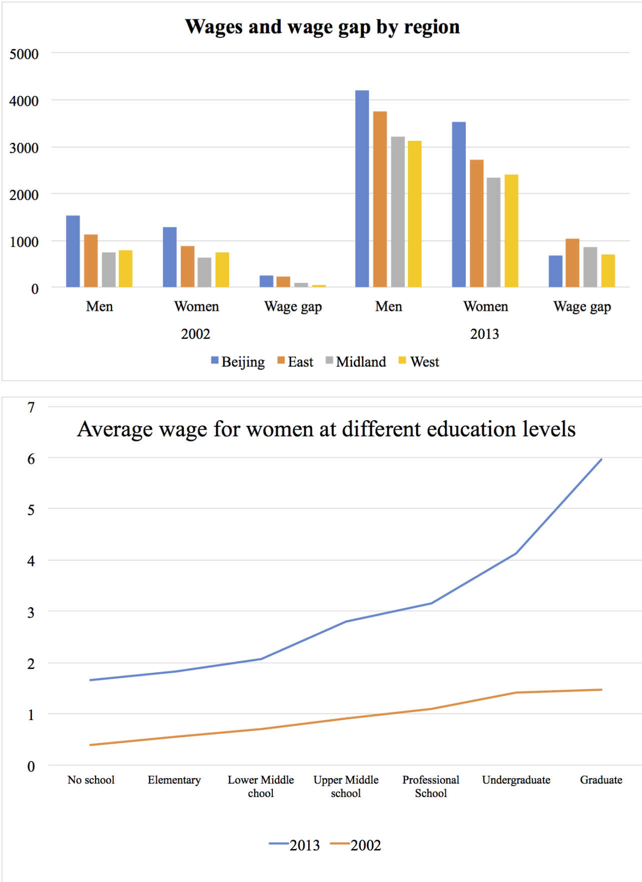

Figure 3: Top:Men and Women wages per region in 2002 and 2010. Bottom: Women's average wage as a function of their education level. Upper Middle school includes middle level professional school.

that if women have very little power within their marriage, then the share of educated boys and girls is zero. Here power is understood as the possibility that women have to retain a share of the couple's income proportional to their individual contribution. If women cannot retain much of the common income, then parents will not educate girls. As a result, men will all marry uneducated women, independently of their own education. Since men will be able to retain most of the couple's income, and since education is costly, it is then worthless to educate boys in this context. Our model can indeed explain the education overtake and provide a sound answer to the puzzle. If the number of potential educated men is high enough and (most important), if women are powerful enough, then the share of educated women can surpass the men's share. Parents need both the perspective of a good marriage, and need to know that their daughters will be able to retain a fair amount of their income.

With these elements in hand, Section 5 calibrates the model using the Chinese census CHIP for 2002 and 2013. Once education and wages for all categories are fixed to their actual values, the cause of the overtake comes to light: women's power increased by an astonishing 60% from 2002 to 2013. That is, traditions, culture, and marriage rules have been forced to evolve extremely fast, as if overwhelmed by the change in the Chinese economy.

The rest of the paper is structured as follows. Section 2 presents the marriage market, including the spouses preferences and the mating mechanism. Section 3 obtains first the number of each type of couple, quantifying the value of education for both men and women. Section 4 solves the problem of the families, and it provides with the optimal equilibria. The afore mentioned calibrated example is presented in Section 5 and finally, Section 6 concludes.

2 The marriage market

Our economy is made of households composed of two generations: parents and their unmarried children. Parents decide whether to provide college education to their children depending on their preferences and the cost of education, taking into account how the education level of their children will influence their future income and their mating opportunities on the marriage market.[3] We assume that the population of girls is 1 and that of boys $\phi > 1$. For simplicity, we say that an individual is educated if she has undertaken undergraduate studies, uneducated if not. Denoting by e^w and e^m the shares of educated women and men, respectively, the amount of educated men and women are then e^w and ϕe^m.

We start by describing the marriage market. Although following Mariani (2012) along the main lines, our marriage market assumes that all households have identical preferences. Population is divided between men and women, who can be educated or

[3]We have made here a probably debatable hypothesis, namely, that parents decide on their children's education. Note first and most importantly that our results and conclussions would remain unchanged if young men and women took education decisions themselves. Second, we have opted for this modeling approach to leave space in a future for families preferences. And third, to put forward that successfully reaching college needs early preparation and specific arrangements from childhood that can only be met by parents or tutors within families.

not. Hence, there are four groups $\left(EW, \bar{E}W, EM, \bar{E}M\right)$, which correspond to educated women, uneducated women, educated men, uneducated men, respectively. Marriage decisions are made taking the educational level as given, since this is decided by parents in the previous period. Consequently, the shares of educated and non-educated men and women are also taken as given.

2.1 Spouses preferences

As in Bergstrom and Bagnoli (1993), Edlund and Korn (2002), Gould et al. (2008) and Mariani (2012), we assume that men and women search for different qualities in their future spouses. Here, men value three distinct aspects of his future household: love, the educational level of his spouse and their future joint income. As a result, the education level of the future spouse has a direct effect on preferences because whether the future partner is educated or not matters, and indirect because an educated mate earns a higher wage, which increases in turn the income of the future couple. We assume for simplicity that future households split the household revenue following an exogenous rule à la Gale-Shapley. Indeed, men will receive a share θ of the future joint income, with $0 < \theta < 1$. Hence, the utility of a man of type $i = EM, \bar{E}M$ is given by

$$U_i^m = \beta L + \alpha_i A + \theta \left(\omega_i^m + \omega^w\right), \qquad (1)$$

where $\alpha_i, \beta, \theta > 0$, and $\theta \in (0, 1)$. L is the love variable and it takes the value 1 if the man marries someone he loves and 0 otherwise. β measures the man's preference for marrying a woman that he loves. Variable A introduces the notion that people prefer to marry someone with their own education level, and α_i measures the strength of assortative education in men's preferences. Therefore for an educated man, $A = 1$ if the woman is educated, $A = 0$ if she is not. For a non-educated man, on the contrary, $A = 1$ if the woman is not educated, $A = 0$ if she is. Total household income, $\omega_i^m + \omega^w$, will depend on the education level of the man and the woman.

To keep our analysis simple, we make the following assumptions:

Assumption 1. *α_i is uniformly distributed over $[0, \beta]$.*

Assumption 1 implies that all types of men are present, ranging from those who do not value education to those who find education as valuable as love.

Assumption 2. *$\beta > \theta(\omega_i^m + \omega^w)$.*

The previous assumptions imply that men consider that love is more important than assorting and income along. Indeed, by Assumption 1, love is more important than education since $\beta > \alpha_i$; and by Assumption 2, $\beta > \theta(\omega_i^m + \omega^w)$, meaning that love is more important than income. As a result, an educated man would prefer to marry a non-educated woman he loves rather than an unloved educated woman. Similarly, he will choose a woman he loves with low income rather than a richer woman he does not love, all else equal. Note that the income of the different groups only depends on their education level. As a consequence, when an educated man chooses an educated woman, not only does he satisfy his preference of an assortative marriage, but he also brings higher future family income and consumption.

One of the main characteristics of this marriage market is that women are acceptors of men's marriage decisions. As such, they only value one quality in their marriage, namely, their after-marriage family income. The utility function of a woman of type j is then

$$U_j^w = (1 - \theta)(\omega^w + \omega^m), \tag{2}$$

where $(1 - \theta)$ is the woman's share of family income.

2.2 Marriage

The marriage game starts before men and women enter the marriage market, given that individuals' outcome depend on the education already attained. Hence, assuming perfect information implies that education levels and the associated income are known to all agents at the beginning of the mating process. Besides, for every woman in the market, men know whether they love her or not.

As in Mariani (2012), we establish a decision sequence in which educated men are first to choose the woman to marry. Marriages of non-educated men are completed afterwards. Noteworthy, men always prefer loved spouses with their same level of education. Then, an educated man will prefer an educated woman that he loves over all other types of woman. However, if an educated man falls in love with an uneducated woman, it is still possible that he marries an educated woman that he does not love, if the utility from the assortative marriage and the higher future income prevail.

The single status is never preferred. This means in particular that all unmarried women who fail to marry an educated man with higher income will marry non-educated men; and the same holds for men.

Mating is random in the sense that women with the same characteristics face all the same probability to marry an educated man. Indeed, the probability of matching depends on the fraction of educated men and women. If there were no preferences for education, the number of matches between educated men and women is $\phi e^w e^m$; between educated men a non-educated women $\phi(1-e^w)e^m$; between non-educated men and educated women $\phi e^w(1-e^m)$ and between non-educated men and non-educated women $\phi(1-e^w)(1-e^m)$. However, when deciding who to marry, men take also income and love into account so that the final number of each type of match depends on men's preferences.

3 The value of education

Next we compute the expected value of education, defined as the utility improvement through education. This improvement in utility is the difference of expected after-marriage income between being educated and non-educated. As in Chiappori et al. (2009), education increases the social status of women in two ways: first, education increases the women's value on the labor market; and second, education increases the probability of having a better marriage. While in Chiappori et al. (2009) education directly increases women's share of marital surplus, here, education facilitates better mariages, with higher joint incomes.

Wages vary across genders and educational levels. Here, we first define the wage of an educated man as $\omega_E^m = \omega$, and define all other wages in relation to ω. Accordingly, the wage of a non-educated man will be expressed as $\omega_{\bar{E}}^m = \lambda\omega$; the wage of an educated woman as $\omega_E^w = \eta\omega$ and that of a non-educated woman as $\omega_{\bar{E}}^w = \rho\omega$, where $0 \leq \lambda, \eta, \rho \leq 1$,and $\rho \leq \eta$. Under these assumptions on the parameters, women earn less than men for all educational levels, and educated individuals enjoy higher wages than non-educated. Note that educated women could earn a higher wage than non-educated men since we have not impose any restriction on the relationship between λ and η.

We need first to quantify the probability that educated men will prefer to marry an uneducated woman. Based on this, we will compute the quantities of the four types of couples plus the number of single men. Only then we will be able to compute the probabilities for the different cases, which are necessary to obtain the value of expected education for men and women.

A non-educated woman can match an educated spouse if an educated man loves her. However, even if loved, she could be replaced by an educated woman and the rate of replacement depends on the utility function of educated men. Indeed, for a non-educated loved woman $L = 1$, $A = 0$ and she offers a salary $\rho\omega$, whereas $L = 0$, $A = 1$ and $\eta\omega$ for an educated woman. Hence, a man whose preference for assortative education is measured by α_i prefers an unloved educated woman to a non-educated loved woman whenever

$$\beta + \theta(1+\rho)\omega < \alpha_i + \theta(1+\eta)\omega,$$

or, simplifying, when

$$\alpha_i > \beta - \theta(\eta - \rho)\omega.$$

Hence there exists a threshold $\alpha^* = \beta - \theta(\eta - \rho)\omega$ for the assortative education preference, such that educated men with a strong preference for education, i.e. $\alpha > \alpha^*$, prefer an educated unloved spouse.

Under Assumption 1, the probability that an unloved educated woman is preferred to a non-educated loved woman, or the probability that $\alpha_i > \beta - \theta(\eta - \rho)\omega$ is

$$P(\alpha_i > \beta - \theta(\eta - \rho)\omega) = \frac{\beta - [\beta - \theta(\eta - \rho)\omega]}{\beta} = \frac{\theta(\eta - \rho)}{\beta}.$$

Hence, the number of non-educated but loved women that can be replaced is $\frac{\theta(\eta-\rho)}{\beta}\phi(1-e^w)e^m$. Nevertheless, the final actual number of replaced non-educated women is constrained by the number of unmatched educated women on the marriage market. The number of unmarried educated women is $e^w - e^w\phi e^m = e^w(1 - \phi e^m)$. If $(1 - \phi e^m)e^w < \frac{\theta(\eta-\rho)}{\beta}(1 - e^w)\phi e^m$, then a quantity $(1 - \phi e^m)e^w$ of all non-educated women will be replaced. If on the contrary, $\frac{\theta(\eta-\rho)}{\beta}(1 - e^w)\phi e^m < (1 - \phi e^m)e^w$ then all non-educated and loved women are replaced by educated non-loved women.

Consequently, there exists a function that relates e^m and e^w, which results from the previous computations and which divides the domain of education decisions. Using the expressions obtained above, let us define then this frontier as the following function

$$e^w(e^m) = \phi\frac{\theta(\eta - \rho)}{\beta}\frac{e^m}{1 - \phi e^m\left[1 - \frac{\theta(\eta-\rho)}{\beta}\right]}.$$

If a couple (e^m, e^w) is above the frontier, we will say that it is in the high region or $(e^m, e^w) \in H$. On the contrary, if (e^m, e^w) is below the frontier, we write $(e^m, e^w) \in L$. Figure 4 describes the frontier and the domain for (e^m, e^w).[4]

[4]We characterize and analyze in detail the frontier in Appendix B.

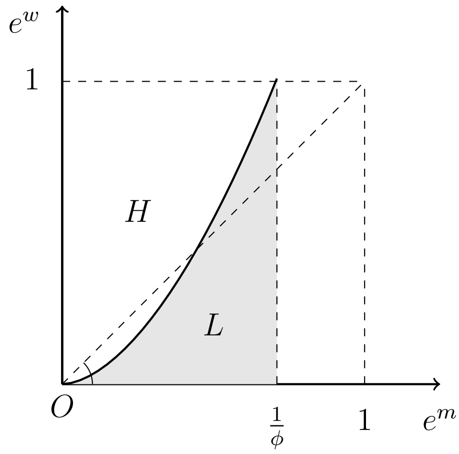

Figure 4: Education decisions depend on whether (e^m, e^w) lie in H or in L.

Let us start by computing the number of the different couples, that we denote by $N(\cdot,\cdot)$. First, we provide the number of couples made by educated men, because they have priority when choosing and because they all get married. The number of couples made of educated men and uneducated women is:

$$N(\bar{E}W, EM) = \begin{cases} \phi e^m(1-e^w)\left[1-\frac{\theta(\eta-\rho)}{\beta}\right], & \text{if} \quad (e^m, e^w) \in H, \\ \phi e^m - e^w, & \text{if} \quad (e^m, e^w) \in L. \end{cases} \tag{3}$$

The number of couples made of educated men and educated women is:

$$N(EW, EM) = \begin{cases} \phi e^m\left[e^w + \frac{\theta(\eta-\rho)}{\beta}(1-e^w)\right], & \text{if} \quad (e^m, e^w) \in H, \\ e^w, & \text{if} \quad (e^m, e^w) \in L. \end{cases} \tag{4}$$

Non educated men choose after and they could remain single. The number of couples made of an uneducated man and an educated woman is:

$$N(EW, \bar{E}M) = \begin{cases} e^w(1-\phi e^m) - \frac{\theta(\eta-\rho)}{\beta}\phi e^m(1-e^w), & \text{if} \quad (e^m, e^w) \in H, \\ 0, & \text{if} \quad (e^m, e^w) \in L. \end{cases} \tag{5}$$

The number of couples where both members are uneducated is

$$N(\bar{E}W, \bar{E}M) = \begin{cases} (1-e^w)(1-\phi e^m) + \frac{\theta(\eta-\rho)}{\beta}\phi e^m(1-e^w), & \text{if} \quad (e^m, e^w) \in H, \\ 1-\phi e^m, & \text{if} \quad (e^m, e^w) \in L. \end{cases} \tag{6}$$

Finally, the number of uneducated men that remain single is $N(\varnothing, \bar{E}M) = \phi - 1$.

3.1 Non-educated women expected revenue

For a non-educated woman, the probability to marry-up is defined as the share of couples $(\bar{E}W, EM)$ over the total number of couples of uneducated women.[5]

In a pure random mating mechanism, the probability of a non-educated woman to match an educated man is the ratio of this type of couple, $\phi e^m(1-e^w)$, over total number of couples that non educated women can do, $1-e^w$. Hence, under pure random matching, the probability of mating an educated man is ϕe^m. Note that under the mating mechanism we consider, $P(\bar{E}W, EM) < \phi e^m$ for any level of e^w. That is, the opportunity of a non-educated woman to marry up decreases with assortative mating.

Associated to these probabilities, we can compute the expected revenue of a non-educated woman, which equals[6]

$$\left[1-\frac{\theta(\eta-\rho)}{\beta}\right]\phi e^m(1+\rho)+\left[(1-\phi e^m)+\frac{\theta(\eta-\rho)}{\beta}\phi e^m\right](\lambda+\rho), \tag{7}$$

if $(e^m, e^w) \in H$, otherwise, if $(e^m, e^w) \in L$ it is

$$\frac{\phi e^m - e^w}{1-e^w}w(1+\rho)+\frac{1-\phi e^m}{1-e^w}w(\lambda+\rho). \tag{8}$$

According to (7), when $(e^m, e^w) \in H$ (and that as a consequence, the share of educated women is relatively large), the expected income of a non-educated woman does not depend on e^w at all, but only on e^m. In this case, income increases with e^m since the probability of mating an educated man increases with the share of educated men, precisely e^m. When there are fewer educated women, i.e. $(e^m, e^w) \in L$, then expected income decreases with the share of educated to non educated women, $\frac{e^w}{1-e^w}$. That is, when there are few educated women, the revenue of the non-educated decreases when the number of educated increases. Obviously, the chance to replace an educated woman is thin when there are few coveted educated women. Expected income of an uneducated woman when $(e^m, e^w) \in L$ increases with the share of educated men only if $e^w > \frac{\lambda+\rho}{1+\rho}$. That is, only when the number of educated women is high enough to satisfy educated men with a strong assortative motive can educated women be replaced by uneducated women, letting the uneducated women's expected income increase.

[5] Detailed computations regarding the different probabilities can be found in Appendix C.

[6] Appendix D provides a throughout description of how the value of education is computed for both men and women.

3.2 Educated Women expected revenue

We can compute educated women's expected income as

$$(1+\eta)\left[\phi e^m + \frac{\theta(\eta-\rho)}{\beta}\frac{\phi e^m(1-e^w)}{e^w}\right] + (\lambda+\eta)\left[1-\phi e^m - \frac{\theta(\eta-\rho)}{\beta}\frac{\phi e^m(1-e^w)}{e^w}\right], \tag{9}$$

if $(e^m, e^w) \in H$, and $1+\eta$ otherwise.

When there are few educated women, i.e. $(e^m, e^w) \in L$, they are guaranteed the maximum income, which is then independent on the number of educated men or women. On the contrary, when there are relatively more educated women, i.e. $(e^m, e^w) \in H$, then expected income increases with e^m because the more educated men the higher the probability of mating an educated man.

3.3 The value of women's education

Education is an asset with which an unmarried woman can increase her status on the marriage market. Accordingly, the value of a woman's education can be defined as the utility gain through marriage when she is educated. Let us denote the value of women's education by Ω^w. Using (7), (8) and (9) we obtain[7]

$$\Omega^w = \begin{cases} (1-\theta)\left[\frac{\theta(\eta-\rho)}{\beta}\frac{\phi e^m}{e^w}(1-\lambda)+\eta-\rho\right], & \text{if} \quad (e^m, e^w) \in H, \\ (1-\theta)\left[\frac{\phi e^m - e^w}{1-e^w}(1-\lambda)+\eta+\rho\right], & \text{if} \quad (e^m, e^w) \in L. \end{cases} \tag{10}$$

The value of women's education has two sources. First, being educated empowers women in the labor market. This is reflected in Ω^w since the difference in salaries $\eta-\rho$ enters (10) regardless of whether $(e^m, e^w) \in H$ or L. Second, being educated also increases the probability of marrying an educated man, which increases further the after-marriage income. This increase in income is shaped by the proportion of educated men and women.

Note that increases in the number of educated men and women have opposite effects on the value of women's education. An increase in e^m increases the value of women's education since it becomes more probable to find an educated man to marry. On the contrary, an increase in e^w decreases the value of education because competition among women increases and finding an educated man becomes more difficult.

[7] Recall that Appendix D contains all computational details regarding the value of education for both men and women.

3.4 The value of men's education

Men's probability of entering each type of marriage, as well as men's expected income obtain following the same procedure as for women's. Defining the value of men's education, Ω^m, as the economic gain of being educated and getting married, it results that:

$$\Omega^m = \begin{cases} \frac{1-\phi e^m}{\phi(1-e^m)}(1-\lambda)\theta + \frac{\phi-1}{\phi(1-e^m)}\left[\theta(1+\rho)-\lambda\right] + (\eta-\rho)\theta\left[\frac{e^w(\phi-1)}{\phi(1-e^m)} + \frac{\theta(\eta-\rho)}{\beta}\frac{1-e^w}{1-e^m}\right], & \text{if} \quad (e^m, e^w) \in H, \\ \frac{1-\phi e^m}{\phi(1-e^m)}(1-\lambda)\theta + \frac{e^w}{\phi e^m}(\eta-\rho)\theta + \frac{\phi-1}{\phi(1-e^m)^2}(\lambda+\rho)\theta, & \text{if} \quad (e^m, e^w) \in L. \end{cases} \tag{11}$$

Men's value of education increases with the share of educated women, e^w, in all cases. Whether men marry educated women or not, a high e^w increases the chances to fulfill their desires. Note that Ω^m obviously increases with θ, the relative power of men in the couple. When there are relatively more educated women, $(e^m, e^w) \in H$, the value of education decreases with λ. Indeed, if the salary of uneducated men increases when educated women are relatively abundant, then men's incentive to educate decreases because they can marry up easily.

A surprising result we obtain here is that the value of men's education increases with the women's wage gap, $\eta - \rho$. The larger the difference between educated and uneducated women's salary, the more men educate to increase their chances to marry an educated women. In this context, marrying an uneducated woman would imply a larger decrease in the couple's income that could surpass even the love motive.

4 The education decision

The previous section showed that the shares of educated women and men influence the value of education in various and different manners. Hence, the family appreciation of e^w and e^m depends on the gender of their children. Accordingly, families are divided into three types: families with only sons, families with only daughters and families with both sons and daughters. Noteworthy, families with only boys or only girls can improve their utility marginally influencing the overall values of e^w or e^m. Families with both boys and girls can influence both.

4.1 Equilibrium

The utility function of family i, which has one son, is equal to the value of educating their son minus its cost:[8]

$$U_i^m = \Omega^m - I_i^m. \tag{12}$$

I_i^m is the cost of education and it is heterogeneous to reflect heterogeneity among boys' learning abilities. That is, the education cost is larger for less abled boys. In particular, let I_i^m be uniformly distributed in $(0, \bar{l})$, where $\bar{l}$ is the maximum for education expenditure. The expected investment in education is then $e^m \bar{l}$. Accordingly, the expected utility of a family with a boy is

$$U^m = \Omega^m - e^m \bar{l}. \tag{13}$$

Families optimize their utility choosing the value of e^m that optimizes U^m, once we replace Ω^m using (18) in (13).[9]

Similarly, for families with only one daughter, utility is given by

$$U_i^w = \Omega^w - I_i^w, \tag{14}$$

where I_i^w is the cost of education. Girls' abilities are also heterogeneous, uniformly distributed as the boys' over the same interval $(0, \bar{l})$. Hence, the expected utility of a family with a girl is

$$U^w = \Omega^w - e^w \bar{l}. \tag{15}$$

The parents of a girl choose e^w so as to maximize U^w. The following assumption is necessary in order to allow for equilibria in which women are better educated than men:

Assumption 3. *The probability that an uneducated women marries an educated man is larger when there men also consider love when taking their marrying decisions, that is*

$$P(EM, \bar{E}M) > P(EM)P(\bar{E}M),$$

which holds if and only if $1 < \phi \left[1 - \frac{\theta(\eta-\rho)}{\beta}\right]$.

[8]For simplicity, we are assuming that the family has only one son. Nevertheless, note that the optimal choice does not vary with the number of sons given that if the family had n sons, then their utility would be nU_i^m.

[9]All computations can be found in Appendix E.

The following proposition shows that there exists an interior equilibrium in the low regime only if education costs are low enough, and if additionally women are sufficiently powerful within their future marriage:

Proposition 1 (Equilibrium in L)**.** *Under the model assumptions, it is necessary that education costs are low enough, $\bar{l} < \phi(1-\lambda)(1-\theta)$, for an interior equilibrium to exist. We distinguish two cases*

- *i) when $\bar{l} < \min\{(1-\lambda)(1-\theta), \frac{\phi-1}{\phi}(\theta(\lambda+\rho)-\lambda)\}$, then there always exists an equilibrium in L.*
- *ii) when $\frac{\phi-1}{\phi}(\theta(\lambda+\rho)-\lambda) < \bar{l} < \phi(1-\lambda)(1-\theta)$, then there exists an equilibrium if*

$$1-\sqrt{\frac{\phi-1}{\phi}\frac{\theta(\lambda+\rho)-\lambda}{\bar{l}}} < \frac{1}{\phi}\left[1-\frac{\bar{l}}{(1-\lambda)(1-\theta)}\right] \tag{16}$$

Proof. See Appendix F. □

Note that in particular, Proposition 1 requires that $\theta > \frac{\lambda}{\lambda+\rho}$.

Corollary 1. *If $\theta < \frac{\lambda}{\lambda+\rho}$, then there is no equilibrium in L.*

Hence, an equilibrium in L is only possible when education costs are low and that women retain enough power in their marriage. We discuss further our results towards the end of the section, once all equilibria are obtained.

There exists a threshold value for e^m, that we denote by ϵ. If $e^m > \epsilon$, then the economy can reach an equilibrium in H in which $e^w > e^m$. ϵ can be obtained taking into account that at that level of educated men, we have at the same time that $e^w = e^m$, and that the pair (e^m, e^w) lies on the frontier. Then

$$\epsilon = \frac{1-\phi-\frac{\theta(\eta-\rho)}{\beta}}{\phi\left[1-\frac{\theta(\eta-\rho)}{\beta}\right]}.$$

In particular, equilibria where $e^w > e^m$ can only happen when both (e^m, e^w) are larger than ϵ.

Proposition 2 (Equilibrium in H)**.** *Under the model assumptions, there exists an equilibrium in H only if $\theta > \frac{\lambda}{\lambda+\eta}$. This equilibrium belongs to the frontier, i.e.*

$$e^w(e^m) = \phi\frac{\theta(\eta-\rho)}{\beta}\frac{e^m}{1-\phi e^m\left(1-\frac{\theta(\eta-\rho)}{\beta}\right)},$$

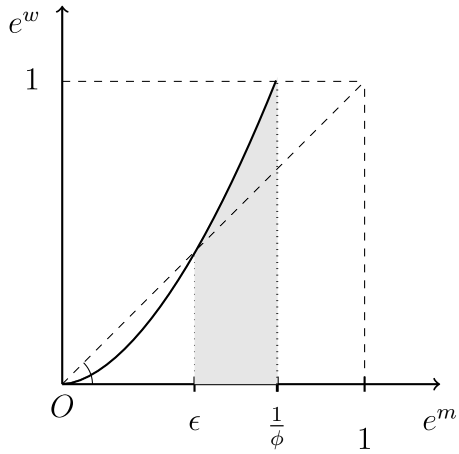

Figure 5: In the shaded region an equilibrium with $e^w > e^m$ can exist.

and it provides higher education to girls if

$$\phi > \frac{(\eta-\rho)\theta}{\lambda-\theta(\rho+\lambda)} \frac{1}{1-\frac{\theta(\eta-\rho)}{\beta}}.$$

Proof. See Appendix G. □

Since the equilibrium belongs to the frontier, it is straightforward to conclude about the influence of each of the model's factors in the equilibrium value of e^w. e^w increases with e^m. Otherwise said, women's education cannot increase without an increase in men's education. Women's education also increases with their relative power θ, and with the relative wage of educated women. In both cases, parents are sure that their daughters can retain a fair amount of the household income, either because they are powerful, or because they earn a high wage. If the wage for uneducated women increases, then education becomes less appealing. Finally, if the love motive gains force, then mating depends less on education and parents will tend to decrease their daughters' education.

We obtain two corollaries when Propositions 1 and 2 are analysed together:

Corollary 2. *If the population of boys is relatively large, $\phi > \frac{(\eta-\rho)\theta}{\lambda-\theta(\rho+\lambda)} \frac{1}{1-\frac{\theta(\eta-\rho)}{\beta}}$, education costs are low enough, $\bar{l} < (1-\lambda)(1-\theta)$, and $\frac{\lambda}{\lambda+\rho} < \theta$, then there exists two equilibria, one in L and one in H. The equilibrium in H provides higher education to girls.*

If women retain enough power within their couple, $\frac{\lambda}{\lambda+\eta} < \theta$, but education costs are

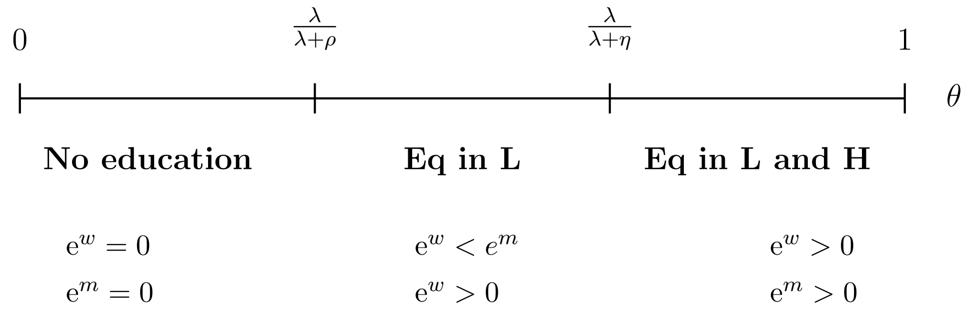

Figure 6: Education decisions as a function of θ.

large or that the population of men is not large enough, then there exists an equilibrium in H, but girls obtain lower education than men.

Corollary 3. *If $\frac{\lambda}{\lambda+\eta} < \theta < \frac{\lambda}{\lambda+\rho}$, then there exists a unique equilibrium in H in which girls can obtain more education than boys.*

We can interpret our results in terms of θ as shown in Figure 6. If $\theta < \frac{\lambda}{\lambda+\rho}$ then there is no equilibrium in which either boys or girls get some education. Women's power is extremely low, and it is not worth educate girls if they cannot retain at least part of their future revenue. Regarding boys, the only advantage for boys' education is the increase in their future revenue. However, families will not engage in education since the large power of the future husband will make him profit from his future wife's salary. This "transaction" makes boy's education less preferable than benefiting from their future wife's revenue.

If $\frac{\lambda}{\lambda+\rho} < \theta$ and education costs are really low (case i) of Proposition 1, then there always exists an equilibrium in L in which both boys and girls get some education. When education costs are larger, like in case ii) of Proposition 1, we can always rewrite (16) as

$$\frac{\bar{l}}{\phi(\phi-1)}\left[\phi - 1 - \frac{\bar{l}}{(1-\lambda)(1-\theta)}\right]^2 < \theta\rho - (1-\theta)\lambda.$$

Notice that the left hand side of the inequality above is bounded from above by $(\phi-1)^2$ when $2(\phi-1)(1-\lambda)(1-\theta) > 1$. In that case, then it is true that

$$\frac{\bar{l}}{\phi(\phi-1)}\left[\phi - 1 - \frac{\bar{l}}{(1-\lambda)(1-\theta)}\right]^2 < \frac{\bar{l}(\phi-1)}{\phi} < \theta\rho - (1-\theta)\lambda.$$

Hence, if $(1-\theta)\lambda < \theta\rho - \frac{\bar{l}(\phi-1)}{\phi}$, that is, the share of her own revenue that an uneducated woman retains is sufficiently low, then parents decide to educate girls to improve their future final income.

When women are empowered enough, $\theta > \frac{\lambda}{\lambda+\eta}$, there is undeterminacy and two equilibria are possible, one in H and one in L. The equilibrium in L always provides less education to girls. Among other characteristics, in L, all educated women are married to educated men because educated women are scarce. In the equilibrium in H, women can get more education than men. Note first that if the number of boys is large enough, then the probability to marry an educated man increases. Furthermore, there are more educated women because even if they marry down, they will retain enough of their revenue to justify the expenses in education.

5 Changing the paradigm

Let us finally address the most important question in this paper, namely what happened in China between the years 2002 and 2009 that reversed the gender pattern in terciary education? Our model's answer is straightforward: women have been empowered in their households. Using the Chinese census on the one hand, and our model on the other, we will show that women's power increased by 60% in the lapse of 11 years. We believe that the education overshoot is also due to the fact that economic and cultural parity will soon arrive, but not yet. Hence, parents educate more girls than boys so that women can have an equal (or larger) stake on the household's income.

Many things and factors changed indeed in China from 2002 to 2009. Not only the economy grew at unprecedented rates, but there were many other signs of rapid changes in the society and the economy: there were 1.1 men for each woman in college age in 2013, more women enrolled in undergraduate studies as from 2009, the average wage gap between men and women increased, and there was a massive migration from rural to urban areas. Besides the wage gap between skilled and unskilled workers also grew, being the gap larger for women. Using data from the CHIP 2002 and 2013 census[10], we obtain the national average wages for skilled and unskilled men and women. Table 1 reproduces the relative changes taking the educated men salary as numeraire for each

[10] As mentioned in the Introduction and explained in Appendix A, we work with the Chinese census, CHIP, which is only available for 2002 and 2013. Hence, we cannot target the interval 2002-2009 but the relatively close 2002-2013 interval.

year, following the paper's notation.

	w^m_E	$w^m_{\bar{E}} = \lambda$	$w^w_E = \eta$	$w^w_{\bar{E}} = \rho$
2002	1	0.6586	0.8737	0.5473
2013	1	0.6333	0.7894	0.4669

Table 1: Skilled and Unskilled average wages for men and women. Source: CHIP 2002 and 2013.

In light of the collected data, it seems clear that the increase in women's college enrollment can not be due to the relative improvement of salaries. Although the salaries of educated women did increase from $1,418$ yuans in 2002 to $4,331.8$ yuans in 2013, they decreased in relative terms with respect to educated men's salaries from 87% to 78%. Let us add that relative salaries for both unskilled men and women also decreased slightly from 54.7% to 46.7%.

Table 2 provides with important information for the calibration of our model regarding the shares of educated men and women, the wage gap and the gender rate in 2002 and 2013. As justified in the following, our conjecture is that in both years, the equilibrium reached was in region H. In 2002, the equilibrium was below the 45^0 degree line, with $e^w < e^m$. In 2013, the equilibrium shifted upwards and to the right, so that both education shares increased, trespassing the 45^0 degree line and yielding $e^w > e^m$. Although it is clear that the 2013 equilibrium was in H, let us show that the 2002 equilibrium was also in H. Indeed, we know from Corollary 2 (and Figure F) that when $\theta > \frac{\lambda}{\lambda+\rho}$, we could encounter equilibria both in H and L. Then, given that the unique information we have is that in 2002 $e^w < e^m$, how can we be sure that the equilibrium lies in H and not in L? Looking at the probability table provided in Appendix C, we learn that in any equilibrium in L, men cannot marry up. However, according to Han (2010), 10% of the men in the marrying cohort 1995-2001 married up. Consequently, we conclude that since men do marry up, then the equilibrium must be in H.

Once this key question has been settled, we compute the implied value for $\frac{\theta}{\beta}$ at the 2002 and 2013 equilibria, using that if the equilibrium is in H, then according to Proposition 2, e^w is a function of e^m: [11]

$$e^w(e^m) = \phi\frac{\theta(\eta-\rho)}{\beta}\frac{e^m}{1-\phi e^m\left(1-\frac{\theta(\eta-\rho)}{\beta}\right)}. \tag{17}$$

[11]This expression is found in Appendix G under the name $e^w_3(e^m)$.

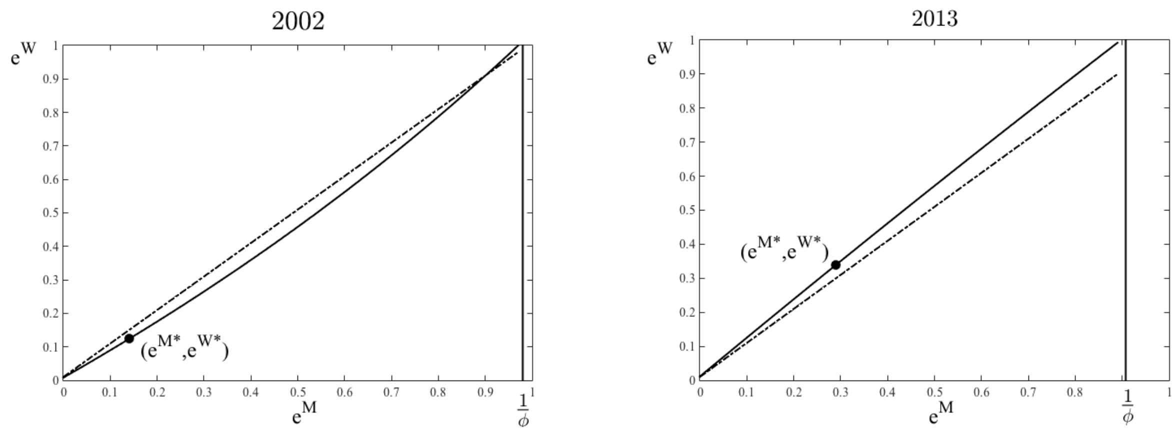

Figure 7: Equilibrium (e^{M*}, e^{W*}) in 2002 and 2013. The solid line is the frontier between H and L, the dashed line the 45^0 degree line.

	e^w	e^m	$\eta - \rho$	ϕ
2002	0.1246	0.15	0.5657	1.02
2013	0.34	0.3	0.4697	1.102

Table 2: Education shares, wage gap, gender ratio in 2002 and 2013.

Substituting e^w, e^m, ϕ and $\eta-\rho$, we find that $\frac{\theta}{\beta}\mid_{2002}= 2.34$ and $\frac{\theta}{\beta}\mid_{2013}= 3.15$. Hence, assuming that the love motive stayed constant over these 11 years, our computations imply indeed a decrease in women's power of more than 34%. Our results indicate that the increase in women's education can be explained by θ, but it is not a response to an increase in women power, but on the contrary, a measure to counterbalance a striking decrease.

Finally, note that since $0 < \theta < 1$, our results imply that $\beta < \theta$, so that income is the most important motive in preferences, dominating love and assortative education.

With more detailed data, our model could also have predicted the shares of men and women marrying up and down, staying single. However, the CHIP census reports the number of singles for groups of age. For instance, we know that 14% of men of ages between 22 and 49 was single in 2013. However, we have treated here each cohort separately, so that we cannot use this data in our model without making further constraining assumptions since in our model.

6 Conclussions

Despite the long standing discrimination towards women in China, there are more women than men enrolled in college undergraduate studies as from 2009. We have built a model to describe the marriage market, choosing some of its characteristics to fit the Chinese case. For instance, we take into account that there are more men than women, that women retain less power without their marriage and that women's wage is lower than men's for the same skill level. We find out that parent's decisions to educate boys and girls hinge on the cost of education along with women's power within their mariage. If the relative power of women is too low, then parents do not educate their children, nor boys neither girls. When women's power increases, then both boys and girls get education. Only when girls power is high enough, that there are potentially enough men to marry and that education costs are not too high could women equalize or/and overpass men. In that case, it could happen that men educate less because they are satisfied with the share of household revenue they retain if marrying an educated woman.

Using the Chinese Census for 2002 and 2013, Section 5 has revealed the reason underlying the education overtake while proving that some other causes are not relevant in the Chinese case. Chinese women do not engage more than men in undergraduate studies because their salary is larger than men's, nor because they are in competition with other women to make good mariages. Women undertake undergraduate studies because they are discriminated in the labor market and, to some extent, at home so that acquiring college education guarantees them with a better position within their mariage.

We leave for future research the questions of heterogeneous households. Indeed, it could be challenging to calibrate and adapt our model at the province level in China to capture more subtleties than our aggregative model. In our research agenda, we also include the dynamic analysis of the present model to explore the long term consequences of all sorts of gender imbalances.

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Appendices

A Data Details

This Appendix describes the sources of the data used in the Introduction as well as the method to construct the different indexes.

- **School enrollment (gross) and Gender parity index (GPI).**

We use the gender parity index to measure the opportunity of girls to attain a given level of education compared with boys. This indicator is calculated by dividing male gross enrollment ratio by female gross enrollment ratio in each education level:

$$\text{GPI of school enrollment} = \frac{\text{male enrollment/male population at that age}}{\text{female enrollment/female population at that age}} \times \text{sex ratio at that age}$$

Although this is a classic indicator, the UNESCO and the World Bank websites do not provide consistent information for China. Furthermore, they do not provide the raw data used to obtain this indicator. As a result, we use here data from the China Population Employment Statistics Yearbook published by the National Bureau of Statistics of China every year, and we calculate the indicator ourselves. The female and male enrollment at primary, secondary and tertiary education level are well published in China Population & Employment Statistics Yearbook, as well as the population by gender at each age. In China, primary school usually starts at the age of 7 and takes 6 years. Then the primary school graduates will spend 6 years in secondary school, and normally 4 years in University (a few special majors in China take 5 years, like architecture and clinical medicine, and some people choose to do short-cycle courses which only take 3 years). Since 1986, children in China are obliged to take at 9 years compulsory education, which contains 6 years of primary education and 3 years of junior secondary education. In this period, they can go to public school for free. Hence, according to the education system in China, we take the female and male population at age 7 to 12, 13 to 15, 16 to 18 and 19 to 22 as the school age of primary, junior secondary, senior secondary and tertiary school age. Then we can calculate the sex ratio at each school age.

• **Gender wage gap.** Here we use the micro data from CHIP 2007 and 2013 to calculate the gender wage gap in China. CHIP (Chinese Household Income Project) is carried out by the China Institute for Income Distribution and Nation Bureau of Statistics to track the dynamic of income distribution in China. Since CHIP 2007, the rural-urban migrant sector has been added to the survey. By convention, CHIP divides China into three areas and makes sure the household samples cover all three areas. In different years CHIP covers households from different cities. To keep it comparable, here we use only data of cities that are covered both in CHIP 2007 and CHIP 2013, which are Jiangsu, Zhejiang and Guangdong representing the East area; Anhui, Henan and Hubei representing the Midland area; and Chongqing and Sichuan representing the West area.

• **Urbanization in China.** The quality of urbanization can be measured by the percentage of urban population. One important signal of urbanization is that people move from rural areas to urban areas. The data used here comes from the World Bank. According to the World Bank, urban population percentage is collected and smoothed by United Nations Population Division.

B Characterization of the frontier

The frontier is defined as

$$e^w(e^m) = \phi\frac{\theta(\eta-\rho)}{\beta}\frac{e^m}{1-\phi e^m\left[1-\frac{\theta(\eta-\rho)}{\beta}\right]}.$$

There exists a value ϵ_* of e^m in $(0,1)$, such that the frontier curve crosses the 45^0 line. Indeed, it suffices to prove that $\frac{\partial e^w(e^m)}{\partial e^m}\mid_{e^m=0}<1$. Hence

$$\frac{\partial e^w(e^m)}{\partial e^m} = \phi\frac{\theta(\eta-\rho)}{\beta}\frac{1}{\left[1-\phi e^m\left(1-\frac{\theta(\eta-\rho)}{\beta}\right)\right]^2} > 0,$$

and it is straightforward to check that $\frac{\partial e^w(e^m)}{\partial e^m}\mid_{e^m=0} = \phi\frac{\theta(\eta-\rho)}{\beta} < 1$.

The frontier is a convex function of e^m since

$$\frac{\partial^2 e^w(e^m)}{\partial (e^m)^2} = 2\phi\frac{\theta(\eta-\rho)}{\beta}\left(1-\phi e^m\left[1-\frac{\theta(\eta-\rho)}{\beta}\right]\right)^{-3} + \phi\left(1-\frac{\theta(\eta-\rho)}{\beta}\right) > 0.$$

The frontier and the 45^0 line cross at the origin $(e^m, e^w) = (0,0)$ and at a point $(e^m, e^w) = (\epsilon, \epsilon)$, where ϵ is defined as

$$\epsilon = \phi\frac{\theta(\eta-\rho)}{\beta}\frac{\epsilon}{1-\phi\epsilon\left[1-\frac{\theta(\eta-\rho)}{\beta}\right]}.$$

That is

$$\epsilon = \frac{1-\phi\frac{\theta(\eta-\rho)}{\beta}}{\phi\left(1-\frac{\theta(\eta-\rho)}{\beta}\right)}.$$

Besides, we can study how the frontier moves with the model parameters: $\frac{\partial e^w(e^m)}{\partial \phi} < 0$, $\frac{\partial e^w(e^m)}{\partial \eta} < 0$, $\frac{\partial e^w(e^m)}{\partial \rho} > 0$, $\frac{\partial e^w(e^m)}{\partial \beta} > 0$.

C Probabilities

Table C below gathers the probabilities for all types of couples, from the perspectives of educated and uneducated women, and then for educated and uneducated men. Probabilities depend on whether $(e^m, e^w) \in H$ or in L.

D The value of education

As mentioned in the article, for a non-educated woman, the probability to marry-up is defined as the share of couples $(\bar{E}W, EM)$ over the total number of couples of uneducated women.

		High	Low
Educated Women	$P(EW, EM)$	$\phi e^m + \frac{\theta(\eta-\rho)}{\beta}\frac{\phi e^m(1-e^w)}{e^w}$	1
	$P(EW, \bar{E}M)$	$1-\phi e^m - \frac{\theta(\eta-\rho)}{\beta}\frac{\phi e^m(1-e^w)}{e^w}$	0
Non Educated Women	$P(\bar{E}W, EM)$	$\left[1-\frac{\theta(\eta-\rho)}{\beta}\right]\phi e^m$	$\frac{\phi e^m - e^w}{1-e^w}$
	$P(\bar{E}W, \bar{E}M)$	$(1-\phi e^m) + \frac{\theta(\eta-\rho)}{\beta}\phi e^m$	$\frac{1-\phi e^m}{1-e^w}$
Educated Men	$P(EW, EM)$	$e^w + \frac{\theta(\eta-\rho)}{\beta}(1-e^w)$	$\frac{e^w}{\phi e^m}$
	$P(\bar{E}W, EM)$	$(1-e^w)\left[1-\frac{\theta(\eta-\rho)}{\beta}\right]$	$1-\frac{e^w}{\phi e^m}$
Non Educated Men	$P(EW, \bar{E}M)$	$\frac{e^w(1-\phi e^m)}{\phi(1-e^m)} - \frac{\theta(\eta-\rho)}{\beta}\frac{e^m(1-e^w)}{1-e^m}$	0
	$P(\bar{E}W, \bar{E}M)$	$\frac{1-e^w}{1-e^m}\left[\frac{1-\phi e^m}{\phi} - \frac{\theta(\eta-\rho)}{\beta}e^m\right]$	$\frac{1-\phi e^m}{\phi(1-e^m)}$
	$P(\text{single})$	$\frac{\phi-1}{\phi(1-e^m)}$	

Table 3: Marriage Probabilities

The value of education for women is the difference between the expected income of educated women and uneducated women, under the two regimes. Hence if $(e^m, e^w) \in H$, then

$$\Omega^w = (1+\eta)\left[\phi e^m + \frac{\theta(\eta-\rho)}{\beta}\frac{\phi e^m(1-e^w)}{e^w}\right] + (\lambda+\eta)\left[1-\phi e^m - \frac{\theta(\eta-\rho)}{\beta}\frac{\phi e^m(1-e^w)}{e^w}\right]$$
$$-\phi e^m(1+\rho)\left[1-\frac{\theta(\eta-\rho)}{\beta}\right] - (\lambda+\rho)\left[(1-\phi e^m) + \frac{\theta(\eta-\rho)}{\beta}\phi e^m\right]$$
$$= \frac{\theta(\eta-\rho)}{\beta}\frac{\phi e^m}{e^w}(1-\lambda) + \eta - \rho.$$

If $(e^m, e^w) \in L$, then the value of education becomes

$$\Omega^w = 1+\eta - \frac{\phi e^m - e^w}{1-e^w}(1+\rho)\frac{1-\phi e^m}{1-e^w}(\lambda+\rho)$$
$$= \frac{1-\phi e^m}{1-e^w}(1-\lambda) + \eta + \rho.$$

Note that after marriage, women get a share $(1-\theta)$ of their revenue. With an abuse of notation, let us use Ω^w to denote after marriage expected revenue. Previous results can be summarized as:

$$\Omega^w = \begin{cases} (1-\theta)\left[\frac{\theta(\eta-\rho)}{\beta}\frac{\phi e^m}{e^w}(1-\lambda)+\eta-\rho\right], & \text{if } (e^m,e^w)\in H, \\ (1-\theta)\left[\frac{\phi e^m - e^w}{1-e^w}(1-\lambda)+\eta+\rho\right], & \text{otherwise.} \end{cases}$$

Next, we compute the value of education for men, so that we need to take into account that when men are married they will get a share θ of the couple's revenue. Whenever they remain single, then they keep all their revenue. Then, when $(e^m, e^w) \in H$

$$\Omega^m = (1+\eta)\theta\left[e^w + \frac{\theta(\eta-\rho)}{\beta}(1-e^w)\right] + (1-\phi e^w)(1+\rho)\theta\left[1-\frac{\theta(\eta-\rho)}{\beta}\right]$$
$$-(\lambda+\eta)\theta\left[\frac{e^w(1-\phi e^m)}{\phi(1-e^m)} - \frac{\theta(\eta-\rho)}{\beta}\frac{e^m(1-e^w)}{1-e^m}\right] - (1-\phi e^w)(\lambda+\rho)\theta\left[1-\frac{\theta(\eta-\rho)}{\beta}\right]$$
$$-\frac{\phi-1}{\phi(1-e^m)}\lambda.$$

We can rearrange the terms to obtain that

$$\Omega^m = \frac{1-\phi e^m}{\phi(1-e^m)}(1-\lambda)\theta + \frac{\phi-1}{\phi(1-e^m)}(\theta(1+\rho)-\lambda) + (\eta-\rho)\theta\left[\frac{e^w(\phi-1)}{\phi(1-e^m)} + \frac{\theta(\eta-\rho)}{\beta}\frac{1-e^w}{1-e^m}\right].$$

If $(e^m, e^w) \in L$, then the value of education for men is

$$\Omega^m = \frac{e^w}{\phi e^m}(1+\eta)\theta + \left(1-\frac{e^w}{\phi e^m}\right)(1+\rho)\theta - \frac{1-\phi e^m}{\phi(1-e^m)}(\lambda+\rho)\theta - \frac{\phi-1}{\phi(1-e^m)}\lambda.$$

Or

$$\Omega^m = \frac{1-\phi e^m}{\phi(1-e^m)}(1-\lambda)\theta + \frac{e^w}{\phi e^m}(\eta-\rho)\theta + \frac{\phi-1}{\phi(1-e^m)}(\lambda+\rho)\theta.$$

We can gather all elements to write

$$\Omega^m = \begin{cases} \frac{1-\phi e^m}{\phi(1-e^m)}(1-\lambda)\theta + \frac{\phi-1}{\phi(1-e^m)} \\ \qquad +(\eta-\rho)\theta\left[\frac{e^w(\phi-1)}{\phi(1-e^m)} + \frac{\theta(\eta-\rho)}{\beta}\frac{1-e^w}{1-e^m}\right], \text{if } (e^m,e^w)\in H, \\ \frac{1-\phi e^m}{\phi(1-e^m)}(1-\lambda)\theta + \frac{e^w}{\phi e^m}(\eta-\rho)\theta + \frac{\phi-1}{\phi(1-e^m)^2}(\lambda+\rho)\theta, \text{otherwise.} \end{cases} \tag{18}$$

E Optimal education decisions

Let us compute first the optimal value of e^m chosen by a family with a boy. Replace Ω^m using (18) in (13), the family expected utility is maximized whenever

$$\frac{\partial U^m}{\partial e^m} = \frac{\partial \Omega^m}{\partial e^m} - \bar{l} = 0.$$

Here, we also need to take into account that there may be two regimes hinging on the share of educated women. Taking the derivative of U^m with respect to e^m, we obtain when $(e^m, e^w) \in H$

$$\begin{aligned}\frac{\partial U^m}{\partial e^m} &= \tfrac{-\phi(1-\phi e^m)+1-\phi e^m}{\phi(1-e^m)^2}(1-\lambda)\theta + \tfrac{\phi-1}{\phi(1-e^m)^2}(\theta(1+\rho)-\lambda) \\ &\quad +(\eta-\rho)\theta\left[\tfrac{e^w(\phi-1)}{\phi(1-e^m)^2} + \tfrac{\theta(\eta-\rho)}{\beta}\tfrac{1-e^w}{(1-e^m)^2}\right] - \bar{l} \\ &= \tfrac{\phi-1}{\phi(1-e^m)^2}(\theta(\lambda+\rho)-\lambda) + (\eta-\rho)\theta\left[\tfrac{e^w(\phi-1)}{\phi(1-e^m)^2} + \tfrac{\theta(\eta-\rho)}{\beta}\tfrac{1-e^w}{(1-e^m)^2}\right] - \bar{l}.\end{aligned} \tag{19}$$

Setting $\frac{\partial U^m}{\partial e^m} = 0$ provides us with a condition on the education levels that maximizes Ω_M in H. We write the result as if e^w was a function of e^m.

$$e^w = 1 - (\eta-\rho)\theta\frac{\bar{l}\phi(1-e^m)^2 - (\phi-1)[\theta(\lambda+\rho)-\lambda]}{1-\phi+\phi\frac{\theta(\eta-\rho)}{\beta}}.$$

When $(e^m, e^w) \in L$, we have that

$$\begin{aligned}\frac{\partial U^m}{\partial e^m} &= \tfrac{1-\phi}{\phi(1-e^m)^2}(1-\lambda)\theta - \tfrac{e^w}{\phi(e^m)^2}\theta(\eta-\rho) + \tfrac{\phi-1}{\phi(1-e^m)^2}[\theta(1+\rho)-\lambda] - \bar{l} \\ &= \tfrac{\phi-1}{\phi(1-e^m)^2}[\theta(\lambda+\rho)-\lambda] - \tfrac{e^w}{\phi e^{m2}}\theta(\eta-\rho) + \tfrac{\phi-1}{\phi(1-e^m)^2} - \bar{l}.\end{aligned} \tag{20}$$

Imposing that $\frac{\partial U^m}{\partial e^m} = 0$, we obtain

$$e^w = (\phi-1)\frac{\theta(\lambda+\rho)-\lambda}{\theta(\eta-\rho)}\frac{(e^m)^2}{\phi(1-e^m)^2} + \frac{\bar{l}\phi(e^m)^2}{\theta(\eta-\rho)}$$

Similarly, let us compute the optimal value of e^w that a family with a girl would choose. Replace Ω^w using (10) in (15), the family expected utility becomes

$$U^w(e^w) = \begin{cases} (1-\theta)\left[\frac{\theta(\eta-\rho)}{\beta}\frac{\phi e^m}{e^w}(1-\lambda)+\eta-\rho\right] - e^w\bar{l}, & \text{if } (e^m, e^w) \in H \\ (1-\theta)\left[\frac{1-\phi e^m}{1-e^w}(1-\lambda)+\eta+\rho\right] - e^w\bar{l}, & \text{otherwise.}\end{cases} \tag{21}$$

Taking the derivative of U^m with respect to e^w, we obtain

$$\frac{\partial U^w}{\partial e^w} = \begin{cases} -(1-\theta)\frac{\theta(\eta-\rho)}{\beta}\frac{\phi e^m}{(e^w)^2}(1-\lambda) - \bar{l} < 0, \text{if } (e^m, e^w) \in H \\ (1-\theta)(1-\lambda)\frac{1-\phi e^m}{(1-e^w)^2} - \bar{l}, \text{otherwise.}\end{cases} \tag{22}$$

Hence, when the share of educated women is high enough, household welfare decreases with the e^w. This means that the choice of the household above the frontier always lies on the frontier. That is, the household chooses e^w such that

$$e^w = \frac{\frac{\theta(\eta-\rho)}{\beta}}{\frac{1}{e^m} - 1 + \frac{\theta(\eta-\rho)}{\beta}}.$$

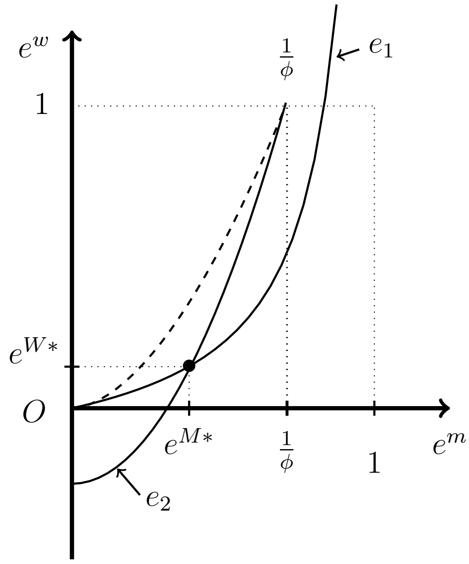

Figure 8: Equilibrium in L when $\bar{l} < \frac{\phi-1}{\phi}\left[\theta(\lambda+\rho)-\lambda\right]$.

In the case e^w is not high enough, we have that expected welfare attains a maximum at

$$e^m = \frac{1}{\phi} - \frac{\bar{l}}{\phi(1-\lambda)(1-\theta)}(1-e^w)^2.$$

F Equilibrium in L

If $(e^m, e^w) \in L$, the equilibrium is given by the intersection of the following two functions

$$\begin{cases} e_1^w(e^m) = (\phi-1)\frac{\theta(\lambda+\rho)-\lambda}{\theta(\eta-\rho)}\frac{(e^m)^2}{\phi(1-e^m)^2} - \frac{\bar{l}\phi(e^m)^2}{\theta(\eta-\rho)}, \\ e_2^w(e^m) = 1 - \sqrt{(1-\phi e^m)\frac{(1-\lambda)(1-\theta)}{\bar{l}}}. \end{cases}$$

Let us begin by inspecting $e_2^w(\cdot)$. Note first that $e_2^w(\frac{1}{\phi}) = 1$ and that $e_2^w(\cdot)$ is an increasing function since

$$\frac{\partial e_2^w(e^m)}{\partial e^m} = \frac{\phi}{2}\frac{(1-\lambda)(1-\theta)}{\bar{l}}\left[(1-\phi e^m)\frac{(1-\lambda)(1-\theta)}{\bar{l}}\right]^{-\frac{1}{2}} > 0.$$

If $e_2^w(0) > 0$, then e_1^w and e_2^w do not cross and there is no equilibrium. Hence, we need to impose that $e_2^w(0) < 0$, which occurs if and only if $\bar{l} < (1-\lambda)(1-\theta)$.

Regarding the first function, note that $e_1^w(0) = 0$. First, we need to ensure that at least in some subinterval of the domain $[0,1]$, the function is increasing. If $e_1^w(\cdot)$ is strictly decreasing, then there is no equilibrium. $\lim_{e^m \to 1} e_1^w(e^m) = +\infty$ if and only if $\theta(\lambda+\rho) > \lambda$. If $\theta(\lambda+\rho) < \lambda$, then $\lim_{e^m \to 1} e_1^w(e^m) = -\infty$ and it is impossible that an equilibrium exists.

Let us compute the derivative of $e_1^w(\cdot)$:

$$\begin{aligned}\frac{\partial e_1^w(e^m)}{\partial e^m} &= (\phi-1)\frac{\theta(\lambda+\rho)-\lambda}{\theta(\eta-\rho)}\frac{2e^m}{(1-e^m)^3}-\frac{2\bar{l}\phi e^m}{\theta(\eta-\rho)} \\ &= \frac{2e^m}{\theta(\eta-\rho)}\left[(\phi-1)\frac{\theta(\lambda+\rho)-\lambda}{(1-e^m)^3}-\bar{l}\phi\right]\end{aligned}$$

If $\theta(\lambda+\rho)>\lambda$, then we know that the derivative tends to ∞ when e^m approaches 1. If the derivative is positive at $e^m=0$, then it will not change sign in the domain. If on the contrary, it is negative at $e^m=0$, then the derivative is negative in some subinterval of the domain starting at $e^m=0$ to become positive later.

Hence, we distinguish two cases:

1. If $\bar{l}<\frac{\phi-1}{\phi}\left[\theta(\lambda+\rho)-\lambda\right]$, then $\frac{\partial e_1^w(e^m)}{\partial e^m}>0$ for all $e^m\in[0,1]$ and there always exists an equilibrium point, that is, $e_1(\cdot)$ and $e_2(\cdot)$ always intersect in $[0,\frac{1}{\phi}]$. This is the case depicted in Figure F.

2. If $\bar{l}>\frac{\phi-1}{\phi}\left[\theta(\lambda+\rho)-\lambda\right]$, then $\frac{\partial e_1^w(0)}{\partial e^m}<0$. $e_1(\cdot)$ and $e_2(\cdot)$ can only intersect if the second root of $e_1(\cdot)$ is smaller than the root of $e_2(\cdot)$. Otherwise, the two curves do not intersect and there is no equilibrium. This case is depicted in Figure F. The root of $e_2(\cdot)$, that we denote x_2 is defined by $e_2(x_2)=0$:

$$x_2=\frac{1}{\phi}\left[1-\frac{\bar{l}}{(1-\lambda)(1-\theta)}\right].$$

The first root of $e_1(\cdot)$ is $e_M=0$. The second, that we denote x_1 is defined by $e_1(x_1)=0$:

$$x_1=1-\sqrt{\frac{\phi-1}{\phi}\frac{\theta(\lambda+\rho)-\lambda}{\bar{l}}}.$$

Imposing that $x_1<x_2$, we obtain the condition for existence in the Proposition.

G Equilibrium in H

If $(e^m,e^w)\in H$, the equilibrium is characterized by the the following conditions:

$$\begin{cases} e_3^w(e^m)=\phi\frac{\theta(\eta-\rho)}{\beta}\frac{e^m}{1-\phi e^m\left[1-\frac{\theta(\eta-\rho)}{\beta}\right]}, \\ e_4^w(e^m)=1-(\eta-\rho)\theta\frac{\bar{l}\phi(1-e^m)^2-(\phi-1)[\theta(\lambda+\rho)-\lambda]}{1-\phi+\phi\frac{\theta(\eta-\rho)}{\beta}}. \end{cases}$$

That is, e^w is at a corner regime as a function of e^m. Indeed, since $\frac{\partial U^w}{\partial e^w}<0$ and $\frac{\partial U^m}{\partial e^w}<0$, then e^w will lie on the frontier, attaining the lowest value in H for a given e^m. The equilibrium will be located at the intersection of $e_3^w(\cdot)$ and $e_4^w(\cdot)$.

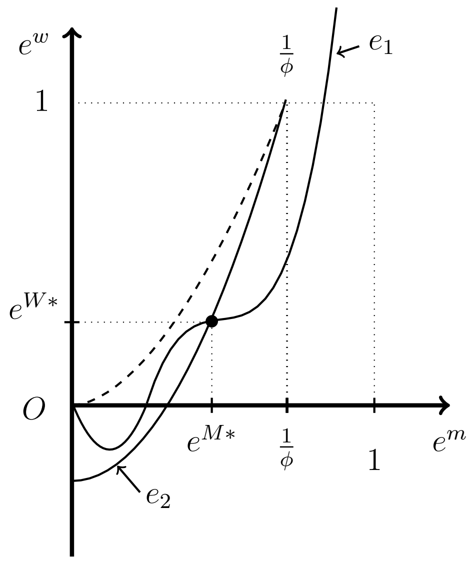

Figure 9: Equilibrium in L when $\bar{l} > \frac{\phi-1}{\phi}\left[\theta(\lambda+\rho)-\lambda\right]$.

$e_3^w(\cdot)$ is the frontier, so we know that it is an increasing function verifying that $e_3^w(0) = 0$ and $e_3^w(\frac{1}{\phi}) = 1$. Additionally, there exists a value of $e_M = \epsilon$ such that $e_3^w(\epsilon) = \epsilon$. That is, $e_3^w(\cdot)$ crosses the 45^0 degree line at ϵ.

$e_4^w(\cdot)$ is a decreasing function. Note that

$$e_4^w(1) = 1 - \frac{(\phi-1)\left[\theta(\eta+\lambda)-\lambda\right]}{(\eta-\rho)\theta\left(\left[1-\frac{\theta(\eta-\rho)}{\beta}\right]\phi-1\right)}.$$

Hence if $\theta < \frac{\lambda}{\lambda+\eta}$, $e_4^w(1) > 1$ and there is no intersection between $e_3^w(\cdot)$ and $e_4^w(\cdot)$. If on the contrary $\theta > \frac{\lambda}{\lambda+\eta}$, then the two curves always cross without any further assumption on the parameters.

Girls obtain more education than boys at equilibrium when the two curves intersect for a value of e^m satisfying $e^m \in [\epsilon, 1/\phi]$.

Then, $\epsilon < M$ if and only if $1-\epsilon > 1-M$, or

$$1 - \frac{1-\phi\frac{\theta(\eta-\rho)}{\beta}}{\phi\left[1-\frac{\theta(\eta-\rho)}{\beta}\right]} > \frac{(\phi-1)[\theta(\lambda+\rho)-\lambda]}{(\eta-\rho)\theta\left(\phi\left[1-\frac{\theta(\eta-\rho)}{\beta}\right]-1\right)},$$

$$\frac{\phi-1}{\phi\left[1-\frac{\theta(\eta-\rho)}{\beta}\right]} > \frac{(\phi-1)[\theta(\lambda+\rho)-\lambda]}{(\eta-\rho)\theta\left(\phi\left[1-\frac{\theta(\eta-\rho)}{\beta}\right]-1\right)},$$

$$\frac{1}{\phi\left[1-\frac{\theta(\eta-\rho)}{\beta}\right]} > \frac{\theta(\lambda+\rho)-\lambda}{(\eta-\rho)\theta\left(\phi\left[1-\frac{\theta(\eta-\rho)}{\beta}\right]-1\right)}.$$

Note that under the model assumptions, if $\theta > \frac{\lambda}{\lambda+\eta}$, then the right hand side is negative and the inequality is always true.

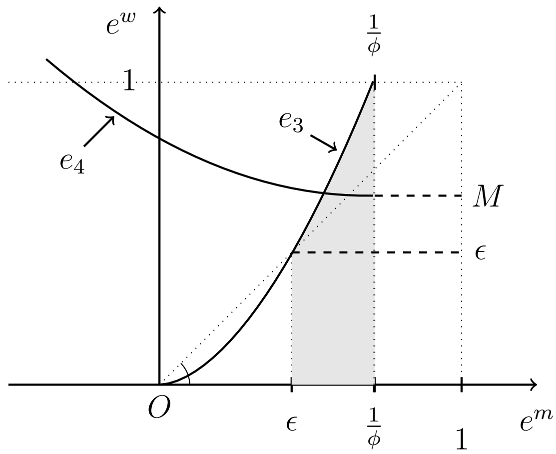

Figure 10: Equilibrium in H.