The Human Capital–Reproductive Capital Trade-Off in Marriage Market Matching

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Throughout the twentieth century, the relationship between women's human capital and men's income was nonmonotonic: while college-educated women married richer spouses than high school–educated women, graduate-educated women married poorer spouses than college-educated women. This can be rationalized by a bidimensional matching framework where women's human capital is negatively correlated with another valuable trait: fertility, or reproductive capital. Such a model predicts nonmonotonicity in income matching with a sufficiently high income distribution of men. A simulation of the model using US Census fertility and income data shows that it can also predict the recent transition to more assortative matching as desired family sizes have fallen.

I. Introduction

It has long been suspected that higher earnings may not always yield women wealthier mates. Early theory on marriage markets predicted that in fact matching should be negative assortative on income because of

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returns to specialization (Becker 1973). Recent research suggests that earning high income itself could make women less desirable to potential partners (Bertrand, Kamenica, and Pan 2015; Bursztyn, Fujiwara, and Pallais 2017). And yet matching is generally *positive* assortative on income, and most literature shows that it has become more so over time (Fernandez, Guner, and Knowles 2005; Schwartz and Mare 2005; Hurder 2013; Greenwood et al. 2014, 2016; Chiappori, Salanié, and Weiss 2017).[1]

In this paper, I posit that underlying these apparent contradictions is the fact that human capital investments that yield greater income may also decrease another desirable marriage market trait, "reproductive capital." Women's fertility decreases with age, and human capital investments that increase income also delay marriage and childbearing and increase spacing between births. I first show that older age at marriage is linked to lower spousal income for women, aligning with experimental findings that men value women's age through the channel of fertility (Low 2023a). I then document for the first time that husband's income has historically exhibited a nonmonotonic pattern in wife's education: additional education up to a college degree was associated with increased spousal income, but education beyond college was associated with decreased spousal income. This pattern cannot be rationalized by a traditional unidimensional model but can be easily explained by a bidimensional model where income is negatively correlated with fertility.

I outline a transferable utility matching model between men characterized by income and women characterized by income and fertility. A latent human capital type impacts both income and fertility. This contributes to a growing literature showing that truly multidimensional models, as opposed to index frameworks, may be crucial in understanding matching patterns, since valuations of nonincome traits likely vary with income (Coles and Francesconi 2011, 2019; Dupuy and Galichon 2014; Chiappori, Oreffice, and Quintana-Domeque 2017; Lindenlaub and Postel-Vinay 2023; Galichon, Kominers, and Weber 2019; Galichon and Salanié 2022). I demonstrate that with a surplus function that is supermodular in both incomes and income and fertility, nonmonotonic matching on incomes can appear. The stable match will depend on the trade-off between human and reproductive capital in women's type distribution relative to men's income distribution. I provide a simple condition such that there always exists a man rich enough that he prefers a higher fertility but poorer woman to a richer and less fertile woman.

Women's educational investment will then depend on the matching penalty, aligning with theoretical and empirical work showing that fertility

[1] Note that Gihleb and Lang (2020) and Eika, Mogstad, and Zafar (2019) do not find increasing assortativeness over time.

concerns can affect career investments (Siow 1998; Dessy and Djebbari 2010; Zhang 2021; Gershoni and Low 2021b) but highlighting the equilibrium matching channel in addition to personal utility loss from lower fertility. Nonetheless, it is possible to sustain an equilibrium where women invest in human capital despite worse matching outcomes, because they value the wage returns over the marriage market penalty.[2]

Finally, I simulate the model using US Census data on income and fertility over time and demonstrate that it can match the evolution of historical patterns. The convergence between highly educated and college-educated women's fertility rates as average family sizes fell can produce the shift from nonmonotonic to assortative mating. This aligns with the reversal of fortune for educated women on the marriage market that has been noted elsewhere (Rose 2005; Fry 2010; Isen and Stevenson 2010; Bertrand et al. 2021) but emphasizes highly educated women as the drivers of this phenomenon. Moreover, the model can match the increase in women pursuing graduate education over time.

Together, these results demonstrate that while we may presume that women value fertility personally, it also affects them economically. This paper uses different levels of education to demarcate human capital investments, standing in for the more general problem of the trade-off between career investments and fertility, which is of first-order concern to women.[3] Individuals, policy makers, and firms may be able to use a better understanding of this trade-off to blunt the impact of reproductive capital's decline.

The remainder of the paper proceeds as follows: section II documents stylized facts, section III develops a bidimensional matching model that incorporates fertility in the marital surplus function, section IV simulates the model, and section V concludes.

II. Stylized Facts

This section establishes two stylized facts: first, that older age at first marriage for women is associated with poorer spouses; and second, that women's human capital, which increases earnings but decreases fertility, has historically been nonmonotonically related to spousal income.

[2] This contributes an example where investments can affect multiple dimensions to the literature on premarital investments (Cole, Mailath, and Postlewaite 2001; Peters and Siow 2002; Iyigun and Walsh 2007; Lafortune 2013; Mailath, Postlewaite, and Samuelson 2013, 2017; Nöldeke and Samuelson 2015; Dizdar 2018).

[3] For evidence that it is difficult to coprocess career investments and fertility, see Goldin and Katz (2002), Bailey (2006), Bailey, Hershbein, and Miller (2012), Adda, Dustmann, and Stevens (2017), Kleven, Landais, and Sogaard (2019), and Gershoni and Low (2021a) for evidence that future reproductive time horizons drive young women's decision-making.

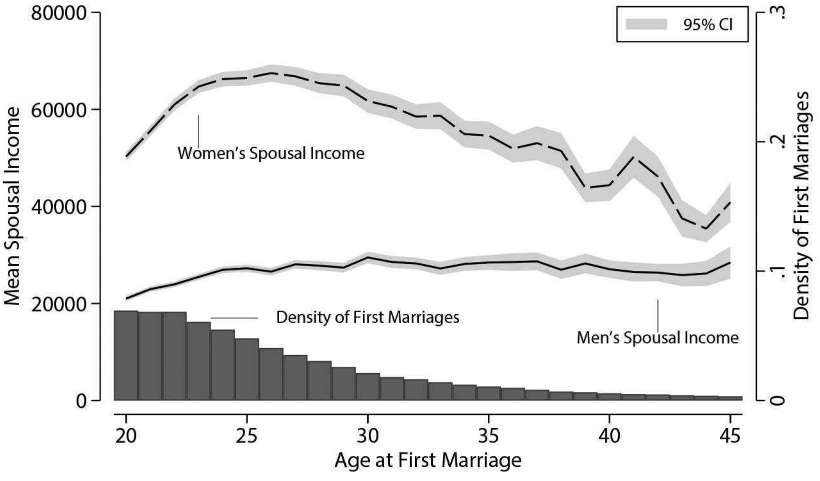


FIG. 1.—Spousal income by age at marriage. Lines represent the average spousal income by age at marriage for women versus men currently in their first marriage. Income is current spousal income for individuals currently 46–55 years old. Bars represent the portion of all women's marriages occurring at that age to check whether selection is driving the effect. Data are restricted to US-born individuals. Source: 2010 American Community Survey (1% sample).

First, figure 1 shows that for women over the age of around 25, each year older that they marry is associated with lower spousal income.[4] Although the negative relationship between women's age and spousal income is only correlational, the fact that individuals who marry later tend to be positively selected makes it suggestive of a negative impact of age on marriage market outcomes.[5]

This aligns with evidence from an incentive-compatible experiment in Low (2023a) that men have a negative preference for women's age when it is randomly assigned to dating profiles. This preference is driven by men with accurate knowledge of the fertility-age trade-off and who have no children themselves, suggesting that it is driven by fertility concerns.

[4] This pattern is shown in women age 46–55 at the time of the 2010 American Community Survey, so that marriages up to age 45 can be shown. To verify that neither the selection of ages nor very late marriages are driving the pattern, fig. A1 (figs. A1–A13 are available online) shows the same pattern for women currently age 36–45, married up to age 35. All US Census data come from the Integrated Public Use Microdata Series database (Ruggles et al. 2010).

[5] One might worry that the pattern stems from unobservable selection, if women who marry later are "leftover." However, the pattern of marriage volume makes this unlikely, since the bulk of marriages—and thus the largest possible sorting—occurs before the decline in husband's income begins, as shown by the density graph. Zhang (2021) additionally notes that the selection of men who marry late tends to be negative, but we do not see the same declining spousal income for men.

If men indeed value fertility as a marriage market trait, it suggests that time-consuming human capital investments would be a double-edged sword for women: on the one hand, human capital carries higher earning, a presumably positive attribute likely to help attract a high-income spouse. On the other hand, income-increasing investments take time, decreasing what could be another valuable asset on the marriage market: reproductive capital.

While much empirical work categorizes all women with college degrees as "college plus," the reproductive capital hypothesis suggests that women with college degrees and graduate degrees may have very different marriage market outcomes, since women with college degrees only could still marry quite young and have large families. Moreover, graduate degrees are correlated with the types of high-investment careers that may continue to interfere with time to have children: the tenure track, the partner track, surgical residencies, and climbing the corporate ladder.

Figure 2 shows that when graduate and college education are treated separately, there has historically been a nonmonotonic relationship between women's education and men's income. All levels of education prior to a graduate degree are associated with higher income, whereas graduate degrees are associated with lower spousal income, up until the

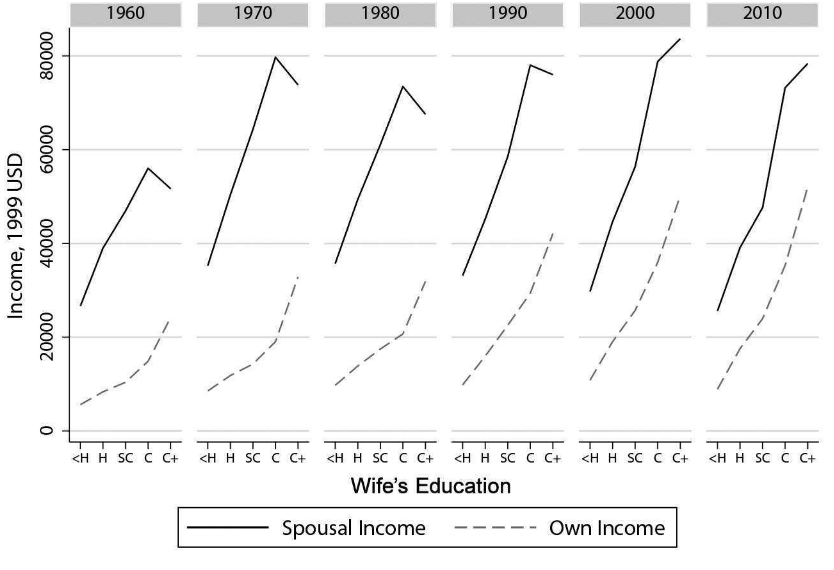


FIG. 2.—Nonmonotonicity in spousal income by wife's education level. Income of spouse is based on wife's education level. <H = less than high school; H = high school graduate; SC = some college; C = college graduate; C+ = graduate degree. Sample consists of US-born women ages 41–50 (married, for spousal income). Source: 1% US Census data from 1960, 1970, 1980, and 1990 and American Community Survey data from 2000 and 2010.

1990s.[6] The relationship between education and own income, by contrast, is monotonic, and in fact own income increases the most steeply between college and graduate education in all years.

The spousal matching penalty to graduate education is statistically significant, as shown in table A1 (tables A1 and A2 are available online), and economically meaningful. In 1970 and 1980, a highly educated woman was married to a man making about $6,000 less than a college-educated woman, despite making over $10,000 more herself. This penalty appears up to the 2000 data, when a monotonic relationship emerges, although there is still less steep growth between the spousal income of a highly educated woman and that of a college-educated woman than between other educational levels.

Unidimensional models fail to match this nonmonotonicity. Division of labor—and thus substitutability between men's and women's incomes—could explain the negative relationship between education and spouse's income for college- and graduate-educated women but not the positive relationship at other education levels. Complementarity in spouses' incomes, social class, or education could explain the positive relationship in most of the data but not the apparent penalty to graduate education.

Moreover, while a relative increase in marriage rates (and decrease in divorce rates) for educated women has been noted in the literature, I show in figure A3 that these changes were actually driven specifically by graduate-educated women. College-educated women have historically had comparable marriage and divorce rates to women with less education. Only highly educated women previously married substantially less and divorced more and have therefore driven the recent reversal.

These facts suggest a second factor that is decreasing in education, even as income rises. Thus, I introduce the concept of reproductive capital, which depreciates with age.[7] Table 1 shows just how substantially highly educated women's fertility differed historically from those with college or lower degrees, using 1970 US Census data. Highly educated women

[6] US Census and American Community Survey 1% sample, restricted to women age 41–50, so that the vast majority of first marriage activity and educational investments have already taken place by the time they are observed. This graph includes all marriages rather than only first marriages, as number of times married is unavailable in 1990 and 2000. To ensure that second marriages are not driving the pattern, in fig. A2 I repeat the analysis for first marriages only, omitting 1990 and 2000, and find entirely comparable patterns.

[7] While other elements in addition to fertility could be negatively correlated with income, they may be less likely to be complementary with income, which is a key driver of the model's ability to produce nonmonotonic income matching patterns. I explore some of these alternative explanations in app. sec. C.4 (apps. A–D are available online). While I cannot rule out that highly educated women have lower tastes for children rather than lower ability to have children, this nonetheless implies a male valuation of fertility. However, suggestive evidence in app. sec. C.4 shows that selection is unlikely to entirely be the driver of the matching patterns we observe, since the spousal income penalty moves little during a time when the number of women seeking graduate degrees doubled. Even if the second factor is something other than fertility, the key point is that the data reflect a duality of human capital investments for women that does not exist for men.

TABLE 1
Women's Income, Spousal Income, Age at Marriage, and Children: 1970 US Census

	≤High School	Some College	College Educated	Highly Educated	Highly Educated − College Educated
Income (US$)	10,173	14,282	19,038	32,864	13,827***
Spousal income (US$)	43,150	64,333	79,710	73,819	−5,890***
Age at marriage	21.15	22.34	23.58	24.23	.65***
Children in household	2.53	2.58	2.65	2.22	−.44***
≥4 children in household	.26	.25	.25	.17	−.08***

Note.—Data are from 1% 1970 US Census for US-born women ages 41–50, except for children in household, which is measured for women ages 38–42 to avoid bias from children aging out of the household, weighted by US Census person weights. Data for children ever born are available in 1970 but not in 2000 or 2010, which is required for the simulations. Additionally, it may not reflect true fertility, since in earlier years infant mortality was more prevalent. Nonetheless, the gap between college-educated and highly educated women for this metric is extremely similar: 0.42 fewer children born and a 0.11 lower chance of having four or more children.

*** $p < .01$.

had almost one-half fewer children on average and were only two-thirds as likely to have more than four children compared with college-educated women. By contrast, there is little difference in these family size metrics between those with college degrees and those with high school education or some college. In addition to marrying older than all other educational levels, highly educated women may also be more likely to make post-education career investments that delay childbearing and increase spacing between children.

Thus, in section III, I develop a model of matching where human capital investments increase income but decrease fertility and explore its implications for the duality of educational investments for women.

III. Theoretical Framework

A. *Model Setup*

If men value women's fertility, it will have consequences for matching patterns as well as women's willingness to invest in human capital. This section studies this using a bidimensional transferable utility matching model. In this model, human capital investments yield earnings gains but can also delay marriage and childbearing, resulting in lower fertility. The dimensions of this model cannot be collapsed to an index, because fertility impacts the household's ability to create surplus through investing income in children, and thus its value is dependent on income.

Transferable utility matching models derive matching patterns from the efficient creation and division of surplus (Shapley and Shubik 1971; Becker 1973). The equilibrium payoff of each individual is set in the market as "offers" where both spouses are able to attract one another. Thus, the model simply requires assumptions on the form of the marital surplus to establish equilibrium matching patterns and resulting utilities. As long as utility is fully transferable, the disaggregate equilibrium will be one and the same as the equilibrium that maximizes total social surplus.

Thus, to determine the stable match, we first must consider how household surplus is created.

1. Household Problem

Men are characterized by income, y, and women are characterized by both income, z, and fertility, p, which represents the probability of successfully conceiving. Individuals value private consumption, q, and children as a public good, Q, which are complementary, producing the underlying force toward assortative matching (Lam 1988).[8] With a single public and private good, the necessary and sufficient condition for transferable utility is generalized quasilinear (GQL) utility (Bergstrom and Cornes 1983; Chiappori and Gugl 2014). The simplest form of GQL is Cobb-Douglas utility, or qQ utility (Chiappori 2017; Chiappori, Salanié, and Weiss 2017), which I modify as $q(Q + 1)$ so that the couple cares about private consumption even if children do not occur. Because utility is fully transferable, the allocation of income between children and private consumption can be found by maximizing the sum of utilities subject to the budget constraint. The impact of biological fecundity is captured by allowing households to invest in Q only if a child is born, which occurs with probability p. If we assume that they have children, the couple's problem is thus

$$\max_{q,Q}\ q(Q+1),$$

$$\text{such that } q + Q = y + z.$$

y:men income
z:women income

Accordingly, the utility maximizing level of q and Q are $q^* = (y + z + 1)/2$ and $Q^* = (y + z - 1)/2$.

If children were born with certainty, this would result in a very standard surplus function that is supermodular in incomes and would thus predict assortative mating on the marriage market. However, households are constrained to $Q' = 0$ and $q' = y + z$ in the case no children realize, with probability $1 - p$. Thus, joint expected utility from marriage, T, is a weighted average between the optimal joint utility if a child is born and the constrained utility from allocating all income to private consumption:

有娃case 没娃case

俩人的utility合一块 $$T(y, z, p) = p\frac{(y + z + 1)^2}{4} + (1 - p)(y + z).$$

u, v of men and women are y and z

[8] This can be thought of as the human tendency to want children to have similar levels of consumption as parents, a driving force in quantity-quality trade-off models.

To find the surplus from marriage, we simply subtract out the utility from being single, which is to consume one's own income.[9] Thus, the marital surplus is $s(y, z, p) = p[(y + z + 1)^2/4] + (1 - p)(y + z) - y - z$, simplifying to

$$s(y, z, p) = \frac{1}{4} p(y + z - 1)^2. \tag{1}$$

2. Properties of Surplus Function 问题多

The surplus in equation (1) is supermodular in incomes and also supermodular in income and fertility. For simplicity, this example uses a binary fertility outcome, but the model is easily extendable to a case with a set of possible family sizes and a probability of achieving each one while maintaining the same properties, as shown in appendix section B.4. This multiple children extension is the one I will use for simulations.

Before providing the specific distribution of types used here, I discuss some general properties of this surplus function. Because of supermodularity in incomes, for any two women of the same fertility level, matching will be positive assortative in incomes. However, when both income and fertility vary, whether the matching is positive or negative assortative on income can depend on the distribution of types and, in particular, the amount of fertility given up for an increase in income. In proposition 3 in appendix section B.1.2, I show that it is generically true for surpluses that are supermodular in both incomes and income and fertility that the stable match depends on the distribution of types.

For this surplus function, the complementarity between incomes relative to the complementarity between income and fertility goes to zero as income goes to infinity. This implies that when income and fertility are negatively correlated, the stable match will always exhibit some section of negative assortative matching on incomes as long as the richest man is "rich enough." In lemma 2 (app. sec. B.1.2), I show that in general, the necessary condition for this to be true is for the surplus to have the property that

$$\lim_{y \to \infty} \frac{\partial^2 s(y, z, p)/\partial y \partial z}{\partial^2 s(y, z, p)/\partial y \partial p} = 0.$$

[9] Because the focus of this paper is educated women, and because nonmarital births make up an extremely small percentage of all births for women with greater than a college degree, I do not consider cohabitation or nonmarital births. Future research may wish to examine the implications of reproductive capital in a model where cohabitation allows couples to capture a subset of the gains from marriages, such as in Calvo (2022).

The intuition for this is that there is substitution between husband and wife's incomes in generating the household surplus but not between husband's income and wife's fertility. Thus, the marginal benefit of wife's income relative to fertility decreases as household income rises.

3. Distribution of Types

To enable a full characterization of the matching equilibrium with this surplus and illustrate the relevant trade-off between income and fertility, I now provide a specific distribution of discrete types.[10]

Women are divided into three types: low income and high fertility, L; medium income and high fertility, M; and high income and low fertility, H. This captures a key feature of biological fecundity: that it declines nonlinearly. As a result, some amount of human capital can be acquired without incurring reproductive capital losses, but larger human capital investments incur a reproductive capital penalty.[11] Roughly, one can think of the three types as being high school–educated, college-educated, and graduate-educated women.

The three types of women have the following income-fertility pairs:

income fertility

	z	p
L	$\gamma - \mu_\gamma$	$\pi + \delta_\pi$
M	γ	$\pi + \delta_\pi$
H	$\gamma + \delta_\gamma$	π

Thus, δ_γ is the income premium to being the high versus medium type, and δ_π is the fertility penalty. μ_γ is the income premium to being the medium versus low type. The mass of the three types of women is first assumed to be exogenously given, as g^K, $K \in$ L, M, H. Section III.C extends the model to allow for endogenous human capital investment.

There is a total measure 1 of women: $g^{\mathrm{L}} + g^{\mathrm{M}} + g^{\mathrm{H}} = 1$. I assume that there are more men than women, and thus only measure 1 of men can be matched.[12] Define the poorest man who receives a match as y_0 and the richest man as Y. Assume that the income parameters are such that

[10] Appendix D shows that a model with continuous female skill produces highly similar predictions for aggregate matching patterns. Thus, illustrating with three types does not limit the model's generality but has the advantage of mapping well onto empirical exercises, where discrete education is typically used as a woman's type, since income is chosen endogenously after marriage.

[11] There may be other costs to education in terms of foregone time or monetary costs. However, for this initial section, the education distribution is assumed to be exogenous. Additionally, it is possible that men make human capital investments as well, but these impact them unidimensionally.

[12] This is for simplicity in pinning down explicit utilities. There could be an equal number of men and women or excess L-type women, with no change to the basic matching patterns.

the poorest matched man's income plus the poorest woman's income is greater than 1 (this ensures interior solutions for the amount invested in children).

B. *Matching Equilibrium*

def of u, v?????

1. Who Marries Whom

A matching is defined as the probabilities for each y for matching with each (z, p) type and value functions $u(y)$ and $v(z, p)$ such that for each matched pair, $u(y) + v(z, p) = s(y, z, p)$. A matching is stable if two conditions hold for all individuals:

$$u(y) + v(z, p) \geq s(y, z, p),$$
$$u(y) \geq y,\ v(z, p) \geq z.$$

That is, the utility received by any two individuals in their current matches must be jointly higher than the surplus they could create by matching together (the equation holds with equality if the pair is married to each other), and all individuals receive a positive benefit to marriage versus the outside option of consuming their own income.

The principle of surplus maximization allows us to think about the stable equilibrium in terms of maximizing the relative benefit of matching with different female types over men's income. The surplus benefits from changing types as a function of men's income are as follows (with high vs. low being the sum of the two).

Medium versus low:

L, M, H

$$\Delta^{\text{M-L}}(y) = s(y, \gamma, \pi + \delta_\pi) - s(y, \gamma - \mu_\gamma, \pi + \delta_\pi)$$
$$= \frac{1}{4}(\pi + \delta_\pi)\mu_\gamma(2y + 2\gamma - \mu_\gamma - 2).$$

as y inc, always positive

High versus medium:

change in couple's utility

$$\Delta^{\text{H-M}}(y) = s(y, \gamma + \delta_\gamma, \pi) - s(y, \gamma, \pi + \delta_\pi)$$
$$= \frac{1}{4}\pi\delta_\gamma(2y + 2\gamma + \delta_\gamma - 2) - \frac{1}{4}\delta_\pi(y + \gamma - 1)^2.$$

y inc may dec deltaH-M

$\Delta^{\text{M-L}}(y)$ is linear and monotonically increasing in men's income. Thus, when fertility is constant, there is always a higher surplus benefit from pairing a higher-income man with a higher-income-type woman, corresponding to the supermodularity in the surplus function. Any stable match must therefore match M women with higher-income men than L women.

$\Delta^{\text{H-M}}$ is quadratic, giving it a unique maximum, as is $\Delta^{\text{H-L}}$. This quadratic form stems from the declining relative complementarity between incomes compared with income and fertility. Therefore, there is a single interval of men that it is maximally beneficial to pair with high-income women. However, this interval may not be the richest men. Note that even when $\Delta^{\text{H-M}}(y)$ is positive over the full range of y, indicating that there is a positive surplus benefit for all men to matching with H women over M women, the richest men may not be matched with the richest women, because they do not receive a sufficient benefit to pay the price these women command.

From this, we can derive the following lemma.

LEMMA 1. Any stable matching will exhibit the following three characteristics. (1) All matched men will be higher income than all unmatched men. (2) All men matched with M women must be higher income than all men matched with L women. (3) The set of men matched with H women must be connected.

Proof. Item 1 follows from the fact that the surplus function is monotonically increasing in men's income (as long as the total household income exceeds 1, which was assumed). Item 2 follows from the fact that the benefit to matching with an M type versus an L type is monotonically increasing in income. Item 3 follows from the fact that the benefit of matching with an H type versus an M or L type is single peaked: if there is a gap in the men who are matched with H women, then the men in the gap must be matched with L or M women. But because the benefit to matching with H women over L or M women is single peaked, it cannot simultaneously be better to be matched with H women on both sides of the gap than in the gap. QED

The options for the match that meet these criteria are illustrated in figure 3, where the x-axis represents women's type and the y-axis represents men's income. For any given set of parameters, exactly one of these match types will be stable. The first picture illustrates standard assortative matching. All other possible match types meet the criteria in lemma 1 and yet feature nonmonotonicity in income matching. A full characterization of the equilibrium as well as a single-variable maximization problem to

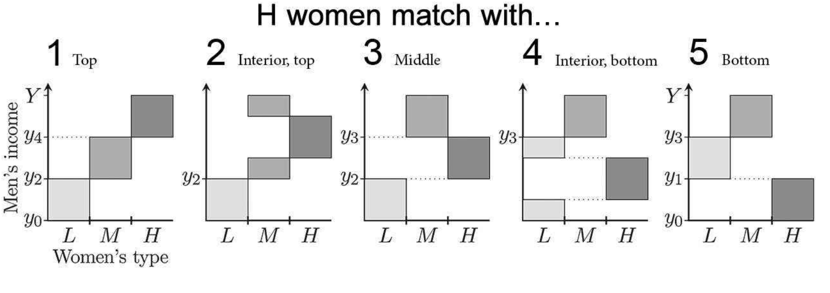


FIG. 3.—Possible matches.

determine the stable match for any set of parameters are shown in appendix section B.2.

Intuitively, the maximization problem to find the stable match is that type H women will be matched with the men who receive the most benefit from matching with them relative to type M or L women. Thus, we can think of characterizing the stable equilibrium as sliding a segment of length h of men who match with type H women from the poorest man to the richest, stopping where the total surplus is maximized. If the man at the top of this segment benefits more than the man at the bottom, we should slide it up. If the man on the bottom benefits more than the man at the top, we should slide it down.

Thus, assortative matching will be stable only when the man with income Y receives more benefit to an H match than the poorest man to be matched with an H type, labeled as y_4 in figure 3.[13] We can thus create a condition for positive assortative matching that $\Delta^{\text{H-M}}(Y) \geq \Delta^{\text{H-M}}(y_4)$ and derive the following proposition. y0 – Y benifits the couple more

PROPOSITION 1. Let Y represent the income of the richest man. For any set of parameters, it is possible to find a Y large enough such that the equilibrium match is nonmonotonic in income.

Proof. Assortative matching requires that $\Delta^{\text{H-M}}(Y) \geq \Delta^{\text{H-M}}(y_4)$, because otherwise the total surplus can be increased by matching the man right below y_4 with an H-type woman and Y with an M-type woman. This condition reduces to $(\pi/\delta_\pi)\delta_\gamma \geq (1/2)(Y + y_4) + \gamma - 1$, which relies linearly on Y. Assume that this condition is met. Increasing Y sufficiently will cause the condition to be violated, in which case matching Y with an H-type woman cannot be surplus maximizing. QED

We can envision moving through each of the equilibria by slowly increasing Y relative to the other parameters. When the condition for assortative mating fails, H-type women match interior to the segment of men matching with M-type women, as shown in equilibrium 2, such that the benefit of the bottom man matching with an H-type woman with income y^* is exactly equal to the income of the top man with income y^{**}: $\Delta^{\text{H-M}}(y^*) = \Delta^{\text{H-M}}(y^{**})$.[14] As Y increases, the segment of men matching with H women will continue sliding down until there are no more M women. At that point, equilibrium 3, where H women are matched exactly between L and M women, will be stable as long as the last man matched with an M woman with income y_3 receives a higher benefit from an H versus L match than the richest man matched with an L-type woman, y_2. If this condition is violated, the segment of men matching with H women will slide down further,

[13] These thresholds have specific definitions in terms of the distributions, but I name them for notational simplicity: $y_4 = F^{-1}(1 - g^{\text{H}})$, $y_3 = F^{-1}(1 - g^{\text{M}})$, $y_2 = F^{-1}(g^{\text{L}})$, and $y_1 = F^{-1}(g^{\text{H}})$.

[14] Where $y^{**} = F^{-1}(F(y^*) + g^{\text{H}})$.

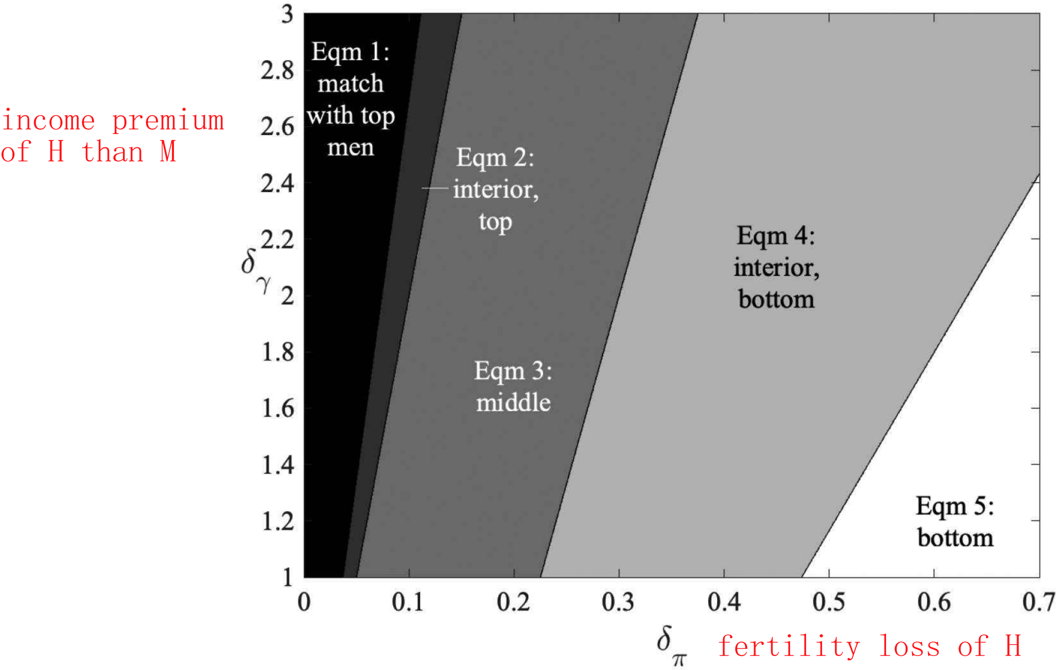


FIG. 4.—Matching equilibrium by return to investment, δ_γ, and fertility penalty, δ_π. For this illustration, men's income ranges uniformly from 0 to 6 (total mass of 1); for women, there is a mass of 0.35 L types, 0.35 M types, and 0.3 H types. M-type income is 4, L-type income is 2. Baseline fertility is a 0.3 chance of conceiving.

interior to the men matching with L-type women, as in equilibrium 4, such that $\Delta^{\text{H-L}}(y^*) = \Delta^{\text{H-L}}(y^{**})$. Finally, if Y continues to increase, at some point the lowest-income man, y_0, will be matched with an H-type woman, as in equilibrium 5. Figure A5 illustrates the conditions on the surplus differences to maintain each equilibrium for a varying distribution of men's income relative to other parameters.

The equilibrium can also be shifted by the distribution of income and fertility in female types. Figure 4 shows the range of δ_γ, the financial return to investment, and δ_π, the fertility penalty, that supports different equilibria types. As δ_γ/δ_π increases, the matching progresses from equilibrium 5 to equilibrium 1, assortative matching. Note that when there is a substantial loss in the probability of successful conception from investments, even very high income premiums do not sustain assortative matching.

2. Utility

Transferable utility matching models allow the direct calculation of each individual's equilibrium utility (value function). This is done by using the equilibrium stability conditions that $u(y) + v(z, p) \geq s(y, z, p)$ and that marriages improve welfare over singlehood. This procedure is shown in appendix section B.3 for a uniform distribution of men's income. Let women's value functions for each type be denoted U^K and the marital surplus each type receives as v^K, constants that depend on the underlying parameters, including δ_π. Then women's equilibrium utility for each type will be

$$
\begin{aligned}
U^{\mathrm{H}} &= \gamma + \delta_\gamma + v^{\mathrm{H}}, \\
U^{\mathrm{M}} &= \gamma + v^{\mathrm{M}}, \\
U^{\mathrm{L}} &= \gamma - \mu_\gamma + v^{\mathrm{L}}.
\end{aligned}
$$

B. 3 talks v^K

Note that individuals maximize the surplus they receive rather than the quality of their partner. So, from the woman's perspective, a nonassortative equilibrium can be viewed as women choosing relationships in which they have more bargaining power, thus receiving a larger share of a slightly smaller pie. They can command this higher surplus share when they create more relative value in relationships with lower-earning partners.

The H type's equilibrium utility function is affected by the fertility loss associated with education both through her own lower utility from children and through the equilibrium channel of a smaller marital surplus share. Figure A12 shows that this equilibrium channel represents a substantial portion of the total welfare loss from lower fertility.

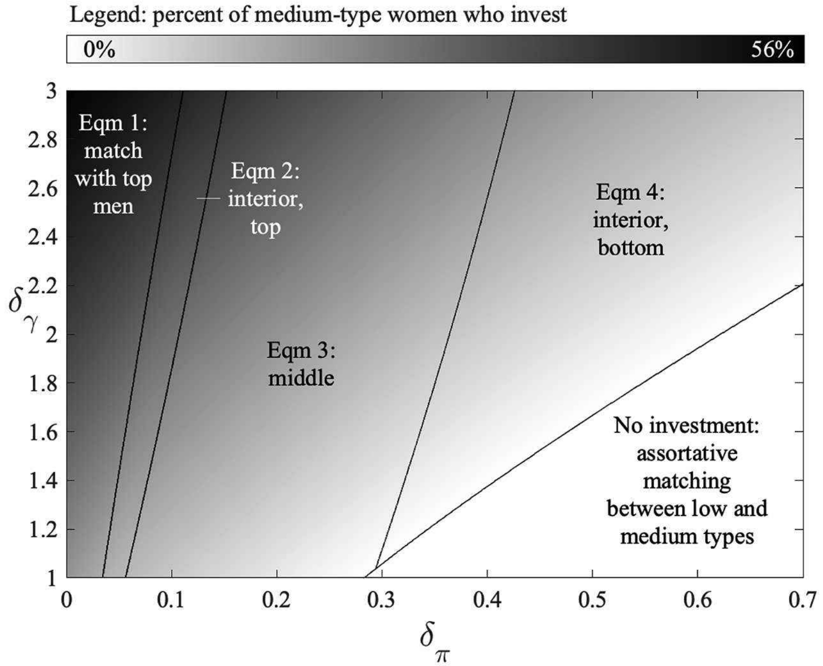
C. Endogenous Human Capital Investment

Both the personal and the marriage market impacts of human capital investment will influence women's willingness to invest in human capital in the first place. The reproductive capital loss creates an extra "tax" on women's human capital investments, reducing the returns to intensive human capital investments. However, it is still possible to sustain an equilibrium where women invest in costly human capital, even if in doing so they forego the most favorable marriage market matches.

Assume that the distribution of L types is fixed but that M types can invest to become H types. Further assume that women considering investing face a heterogeneous utility cost c_i of investment. Using the equilibrium value functions, women will invest in becoming the high type when

$$
\begin{aligned}
c_i &\leq U^{\mathrm{H}} - U^{\mathrm{M}} \\
&\leq v^{\mathrm{H}} - v^{\mathrm{M}} + \delta_\gamma.
\end{aligned}
$$

The mass of H types will now be endogenously determined as a function of the underlying density of c_i. This mass affects the marital surpluses for each female type through its impact on the y at the boundary between



assumption of income to diff

FIG. 5.—Matching equilibrium and investment by income return and fertility penalty. The figure illustrates the δ_γ and δ_π space that supports each matching and investment equilibrium. Bounds are calculated with men's income uniform from 0 to 6 and, for women, M-type income of 4 and L-type income of 2, with a mass of 0.35 L types and 0.65 M types who have the option to invest. Baseline fertility is 0.3. Cost of investment ranges uniformly from 0 to 12.

different wife types. Thus, the cutoffs for women investing can be solved for as a fixed point of $c_i = v^{H}(c_i) - v^{M}(c_i) + \delta_\gamma$. Call the solution to this equation $\hat{c}$. There will be a unique equilibrium where all women with costs below $\hat{c}$ invest in becoming the H type and then match according to proposition 1. If no women invest, the matching will be assortative between L and M types. The threshold cost for investment $\hat{c}$ is decreasing in δ_π (fewer women invest as the fertility cost rises) and increasing in δ_γ (more women invest as the income premium rises). competition?

Figure 5 illustrates the portion of women who invest and resulting matching equilibria for different income gains and fertility costs of investments as well as a uniformly distributed utility cost.[15] Importantly, some women invest in all possible marriage market equilibria, except when H-type women are matched with the absolute lowest-income men.

[15] The thresholds for the matching equilibria are somewhat different than in fig. 4, as the equilibrium responds endogenously to the number of educated women on the market.

The figure illustrates the interesting difference in the forces driving women's investment decision versus the marriage market equilibrium. Women's investment changes more in δ_{γ}, the financial return to investment, while the marriage market equilibrium is more influenced by δ_{π}, the fertility penalty. This is because women get the direct financial benefit of their investment in addition to the marriage market payoff and thus receive an extra financial incentive to invest that does not appear in the marital surplus, which is what influences the matching equilibrium. Thus, women may still be better off investing than not, even if they experience a lower match quality as a result.

D. Predictions

The model predicts that the matching relationship between men's and women's income can be nonmonotonic. If income and fertility are negatively related in the distribution of women, the richest men will not be matched with the richest women as long as either the fertility-income trade-off is large enough or the income of the richest man is high enough. This prediction matches the stylized facts shown in section II.

The model additionally predicts that if either δ_{π} (the fertility penalty to investment) falls or δ_{γ} (the income premium) rises, matching will become more assortative at the top of the female income distribution, and women will invest more in human capital.

Historically, δ_{γ} has been increasing over time, as the skill premium rises and women experience fewer barriers in high-earning professions. And δ_{π} has fallen over time because of both improved technology and falling desired family sizes.

The model could also be extended to predict higher marriage and lower divorce rates for highly educated women over time by using a stochastic joint shock that makes some couples choose not to marry and others to divorce. Higher-surplus couples would be more resilient to higher shocks, and so marriage would be proportional to the surplus of the couple, with the surplus in couples with high-income women rising as matching becomes more assortative and they match with richer men.

IV. Simulation

In this section, I demonstrate the relevance of a bidimensional model with reproductive capital to historical data by simulating the model with moments from US Census data and demonstrating that it can match shifts in matching patterns and marriage rates over time. Note that although this simulation exercise is quite simple, its goal is to demonstrate that a bidimensional model where education affects income and fertility can be useful in explaining observed patterns in marriage market matching. By replicating the shift in matching patterns over the past 50 years, this section shows that the phenomenon of increased assortative mating at the top of the distribution can be explained only by shifts in highly educated women's relative fertility and income, without requiring broader changes in social norms.

To make the simulation more realistic, this section allows families to have multiple children by introducing a slightly more complex structure than a single fertility probability. Instead of constraining investments in children to be zero with probability p, households have a probability p_c of achieving each family size c and are constrained in child investments proportionally on the basis of realized family size, resulting in the following surplus (see app. sec. B.4 for details on how this surplus is produced from the underlying household problem):

$$s(y, z, p) = \sum_{c=0}^{4}\left(p_c\left(y + z - \frac{c}{4}\frac{y + z + 1}{2}\right)\left(\frac{c}{4}\frac{y + z - 1}{2}\right)\right) - y - z. \qquad (2)$$

A. Data Moments

Two key pieces of data from the decadal census are used to feed the simulation: first, incomes of men and women conditional on education; second, an education-specific fertility distribution. For income, men's income is drawn unconditional on education, and then a net present value is calculated to approximate lifetime earnings. The patterns shown are not sensitive to the exact method of approximation. Women's income is drawn conditional on educational level for women working full-time, proxying the earning potential of a given education level, since couples may decide to reallocate women's human capital toward home production. Details are provided in appendix section C.1.

For fertility, I use the empirical distribution of number of children conditional on education. As shown in figure 6, in 1970 highly educated women had substantially fewer children and a higher probability of having zero children than college-educated women, while college-educated women do not have a lower chance of having children than those with lower education levels. Highly educated women marry approximately 1 year older than college-educated women on average, but the fertility difference likely also stems from longer child spacing and a higher opportunity cost of maternity leave. Thus, I take the overall lower fertility as the best measure of the trade-off in reproductive capital from achieving higher income.

These moments change over time, which will drive changes in matching patterns in the model. Market opportunities for women have naturally risen dramatically in the past 50 years (Hsieh et al. 2019). However, a more dramatic shift might come from changes in the fertility penalty

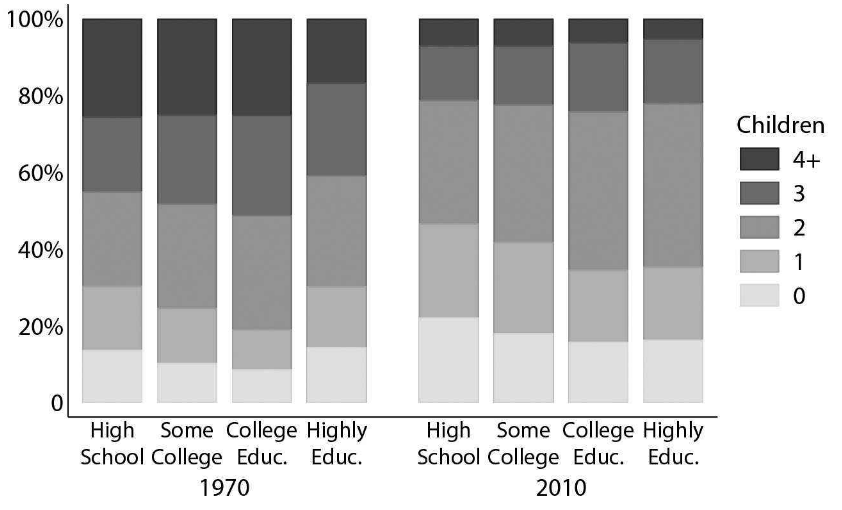


Fig. 6.—Empirical distribution of children by education level and year. Children are currently at home for US-born women ages 38–42. Children ever born, available only through 1990, produce qualitatively similar results in figure A6. "Highly educated" constitutes all graduate degrees. Source: 1% US Census data from 1970 and American Community Survey from 2010, weighted by person weights.

associated with investment. One reason is changing technology, including fertility drugs, in vitro fertilization, surrogacy, egg donation, and egg freezing (e.g., Gershoni and Low 2021a, 2021b). Perhaps more importantly, a trend toward smaller family sizes (Gould, Moav, and Simhon 2008; Doepke and Tertilt 2009; Isen and Stevenson 2010; Preston and Hartnett 2010) causes college-educated women's fertility to be more comparable to highly educated women's fertility, as shown in figure 6, where college- and graduate-educated women have a nearly identical fertility distribution by 2010. This change could be driven by an increasing preference for child quality over child quantity, which tends to accompany economic development (Becker, Murphy, and Tamura 1990).[16]

B. Simulation Compared with Data

Figure 7*A* shows the actual spousal incomes for women of different education levels over time from US Census data. Figure 7*B* simulates these same changes using hypothetical spouses from matching according to

[16] Not only did actual family sizes fall, but also desired family sizes have fallen substantially. During the 1970s, there was a rapid transition from "four or more" as the modal answer for ideal family size to "two," shown in fig. A7 (Livingston, Cohn, and Taylor 2010).

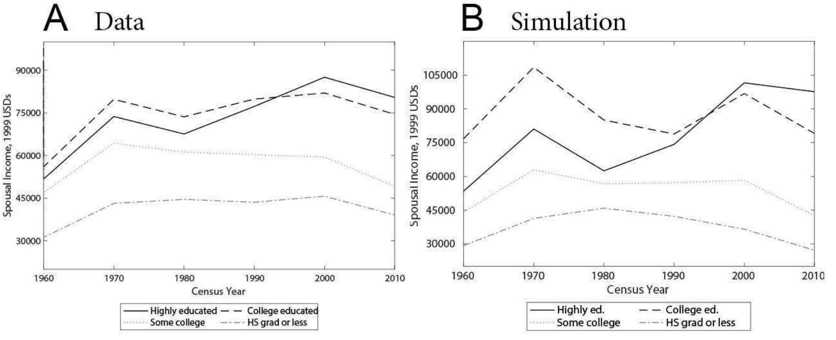


FIG. 7.—Spousal income by education group. Data in *A* are from 1% US Census from 1960, 1970, 1980, and 1990 and American Community Survey from 2000 and 2010, US-born women ages 41–50, weighted by US Census person weights. *B* is a model simulation taking random weighted draws of income (conditional on education for women) and then calculating a net present value of approximate lifetime income. Fertility distribution is for US-born women ages 38–42, so children are still at home. Income is translated into a net present value of 25 periods for men and 20 for women (robust to other choices). With these inputs, matches are determined to maximize total surplus, and then average income of predicted spouse is graphed by education group.

surplus maximization of the function in equation (2), plugging in the income distribution of men and women and the empirical distribution of children over time.

If we use just these moments from the data, the simulation matches the nonmonotonic pattern between wife's education and husband's income throughout the twentieth century. Simulated spousal income increases in education up to a college degree and then decreases for women with graduate degrees, reflecting the lack of a substantial fertility trade-off for educational investments up to college.

Then, driven only by changes in income and fertility over time, the simulation captures the crossing between the spousal incomes of college-educated and graduate-educated women, matching the timing between the 1990 and 2000 censuses. The matching patterns between other groups remain stable in the simulation as they do in the data. While the simulation somewhat overestimates the differences between groups, as individuals are assumed to match on income and fertility only, it demonstrates that even a very simple model incorporating fertility can explain the transition from a nonmonotonic relationship between spousal income and women's education to assortative matching.

Figure 8 compares the actual path of women's investment in graduate education with that predicted by the model. The distribution of the cost of education, c_i, is calibrated to match the rates of graduation in 1970. If we use that same cost distribution, the model matches the increase in 1980 and 1990, although it slightly overestimates the increase in 2000 and

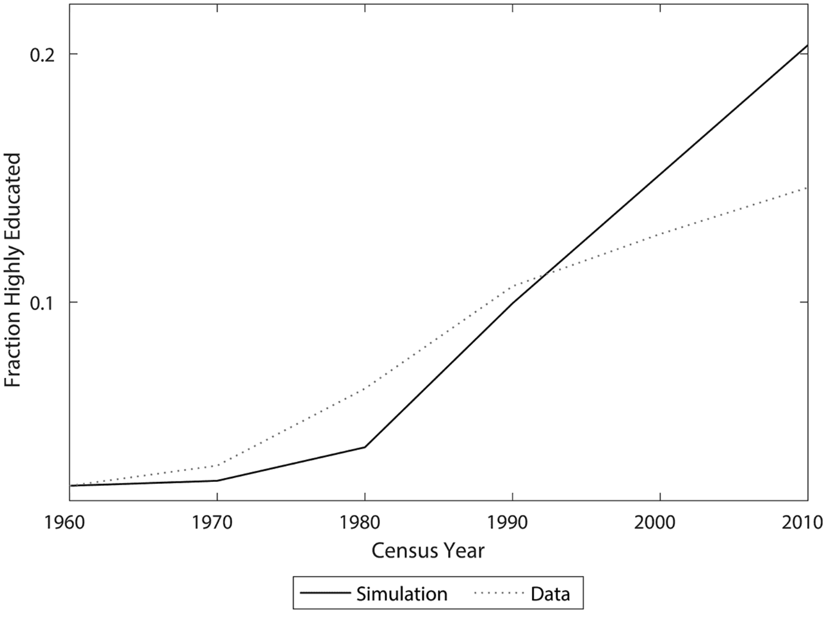


FIG. 8.—Predicted education. The figure is a model simulation of endogenous education decision with uniform education cost, taking a net present value of approximate lifetime income conditional on education and fertility as inputs. Matching and education decisions are determined to maximize surplus, as the private education decision will match the efficient equilibrium.

2010. Note that the distribution of c_i used in the simulation is uniform—a cost distribution with lighter tails may do a better job matching changes in later years. Nonetheless, this demonstrates that even a simulation of the model without extensive calibration can rationalize historical facts.

When the spousal matching patterns are reestimated using endogenous education decisions, matching patterns are similar, although it exaggerates the difference between highly educated and college-educated women's spousal income in later years because of the additional selection effect, shown in figure A8. The model can also produce a simulation of marriage rates that matches the increasing rates of marriage for highly educated women relative to college-educated women over time, shown in figure A9.

This exercise demonstrates that a model where women's reproductive and human capital both matter in matching can help explain historical patterns in women's education decisions and marriage market outcomes. The model's bidimensionality is key to its success in matching the nonmonotonic relationship between wife's education and husband's income until recently and then the later move toward assortative matching.

V. Conclusion

This paper treats women's decisions as a trade-off between two assets: human capital, which grows on the basis of investment, and reproductive capital, which depreciates with time. I develop a bidimensional marriage matching model where women's career investments affect both human and reproductive capital. Matching is predicted to be nonmonotonic when men at the top of distribution are sufficiently wealthy and when the fertility cost of career investments are large relative to the income gains. This adds a second cost to women considering time-consuming career investments: not only do they themselves potentially lose out on fertility, but also they experience a tax on the marriage market as well.

This paper provides an example where a bidimensional matching framework is crucial to rationalizing surprising patterns in the data. Moreover, it explores the occurrence of nonmonotonicity in income matching as a potentially general feature of such bidimensional models where the traits on the bidimensional side are negatively correlated.

I document in US Census data that until recently, marriage matching followed the nonmonotonic pattern predicted by the model. As family size desires fell and reproductive technology expanded, equalizing family sizes between college- and graduate-educated women, there has been a transition to more assortative mating, higher rates of graduate education, and higher marriage and lower divorce rates for graduate-educated women. These patterns are matched by a simulation of the model.

Through the marriage market channel, the fertility impacts of human capital investments will impact women economically, whether or not they desire children themselves. Thus, reproductive capital may be an important consideration in understanding both marriage patterns and women's human capital decisions over time.

Data Availability

Data and code for replicating the tables and figures in this article can be found in Low (2023b) in the Harvard Dataverse, https://doi.org/10.7910/DVN/QUGFLI.

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