Pricing the Biological Clock: Reproductive Capital on the US Marriage Market

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Abstract

Women's ability to have children declines sharply with age. This fecundity loss may negatively affect marital prospects for women who delay marriage to make career investments. I incorporate depreciating "reproductive capital" into a frictionless matching model of the marriage market, where high-skilled women are likely to make pre-marital career investments. When the fertility costs of these investments are large relative to the income gains, the model predicts non-assortative matching at the top of the income distribution, with the highest-earning men forgoing the highest-earning women in favor of poorer, but younger, partners. However, if women's incomes rise or desired family size falls, high-skilled women may be able to compensate their partners for lower fertility, leading to assortative matching. Historical patterns in US Census data are consistent with these predictions. In the 1920-1950 birth cohorts, women with post-bachelors education match with lower-income spouses than women with only college degrees, while in recent years this trend has reversed. The model relies on men internalizing their partners' expected fertility when choosing a mate. I test this using an online experiment where age is randomly assigned to dating profiles, to control for other factors (such as beauty) that change with age in observational data. I find that men, in contrast to women, have a strong preference for younger partners, but only when they have no children of their own and are aware of the age-fertility tradeoff.

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1 Introduction

Women's ability to conceive children falls off rapidly around age 40. This decline in fecundity has rarely been treated as an economic factor, despite large potential implications for women's welfare. If marriages are formed partly to have children, and marriages tend to improve the economic circumstances of women, then a woman is economically worse off after age-induced infertility than before. If she is unmarried, her value as a partner has diminished and thus her marital prospects are worse; if she is married, her outside option has decreased. Thus, fecundity can be thought of as a depreciating economic asset, which I call "reproductive capital."

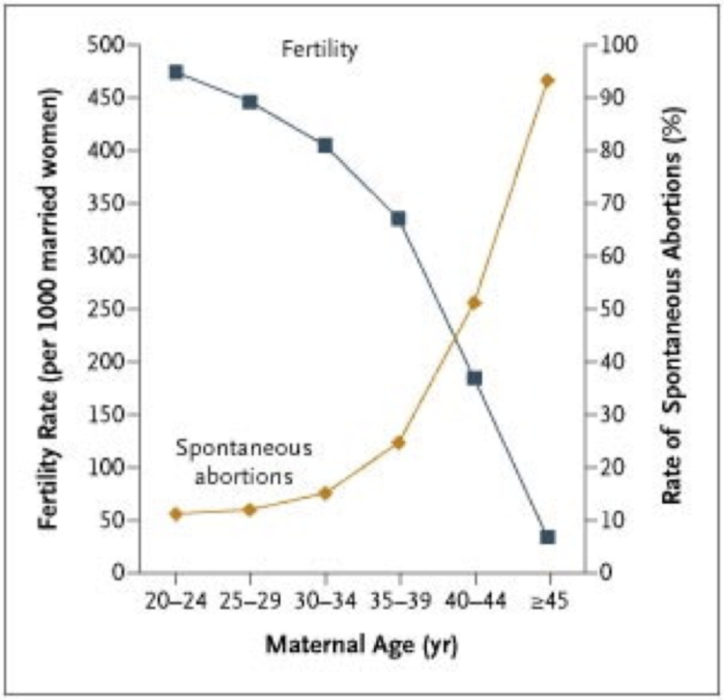
This paper explores how this asset is valued on the marriage market and, consequently, the trade-off women face when making career investments that delay marriage. First, I use a bi-dimensional matching model to study marriage patterns when the most skilled women are likely to marry later. I then document that US Census data exhibits the model's predicted patterns. Finally, I use an online experiment to confirm the model's underlying mechanism, men internalizing their partners' expected fertility, in isolation from potential confounding factors.

Figure 1 shows the stark consequences of aging for female reproduction. Although menopause does not occur until around age 50, women face increasing difficulty becoming pregnant, and having healthy children, as they approach and pass 40 (Frank, Bianchi, and Campana 1994). This decline is not linear from the onset of fecundity, but rather happens sharply beginning in the mid-thirties. Women lose 97% of eggs by 40 (Kelsey and Wallace 2010), while remaining egg quality declines (Toner, 2003). Figure 1 shows the non-linear decline in fertility with age in traditional societies where women do not use birth control, and thus fertility may more closely mirror fecundity.[1] Figure 1 also shows that miscarriages increase sharply with maternal age (measured using hospital records on pregnancies in Denmark between 1978 and 1992), as do fetal abnormalities (Hook, et al., 1983), meaning that even when later-life pregnancy is possible, healthy births are increasingly difficult.

On the marriage market, the differential impact of aging on women appears to be reflected in

[1]Extrapolations of later-life fecundity levels from fertility in traditional societies may suffer from downward bias due to potentially declining rates of intercourse with age, and lower overall health and access to medical care in societies without contraceptive use. However, even more recent prospective studies that show that many women in their late thirties can successfully conceive nonetheless show an accelerating decline in fecundity by age 40 for women, whereas men's fertility is relatively stable. For example, Rothman, et al. (2012), in a prospective study of 2,820 Danish women trying to conceive, find that women 35-40 years old will become pregnant 77% as frequently as women age 20-24, whereas for men this ratio is 95%.

Figure 1: Rates of Infertility and Miscarriage (Spontaneous Abortion) Increasing Sharply with Age



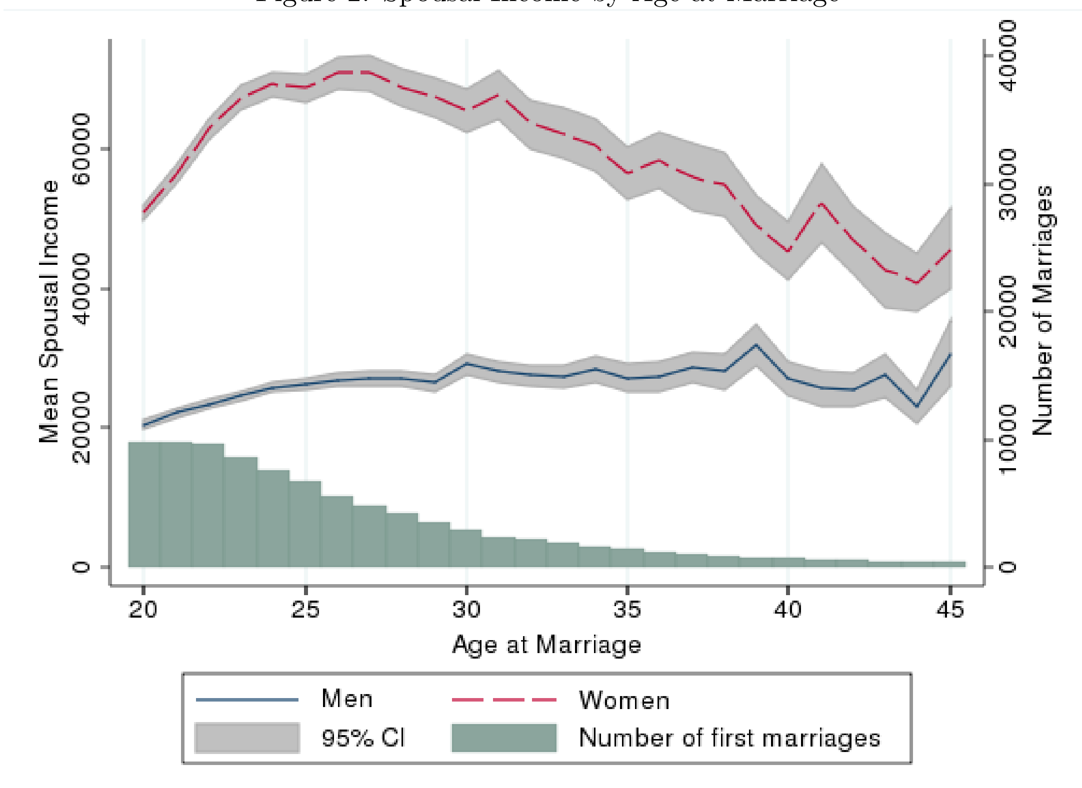
Source: Heffner 2004, "Advanced Maternal Age: How old is too old?"

Notes: Fertility adapted from Menken, Trussell, and Larsen (1986), including Hutterites in the early 1900s, Geneva bourgeoisie from the 15-1600s, Canada in the 1700s, Tunis in the 1800s, Normandy in the 16-1700s, Norway in the 1800s, and Iran in the 1940s, all of which demonstrate the same pattern when studied separately. Spontaneous abortions adapted from Andersen, et al. (2000), comprising data on over 600,000 women in Denmark between 1978 and 1992.

a societal preference for younger female, but not male, partners. Women who are older at the time of first marriage (beyond age 30) tend to marry lower-income spouses, as evidenced by data from the 2010 American Community Survey in Figure 2. In contrast, men's age is not systematically related to the income of their spouse. This pattern linking age and marriage-market outcomes for women motivates a matching model in which career investments influence both income and age at the time of marriage, which in turn affects fertility.

The model incorporates reproductive capital into a transferable utility matching framework: men are characterized by their income, while women have both income and fecundity. This second dimension creates a tradeoff for women between increasing their income and maximizing reproductive capital. When skilled women make time-consuming career investments, the resulting marriage market patterns can be non-assortative on income—the highest-earning men may forego match-

Figure 2: Spousal Income by Age at Marriage



Notes: From 2010 American Community Survey (1% sample) marital histories for white women, 46-55 years old.

ing with the highest-earning women in favor of lower-earning, more fertile partners. This in turn increases the cost to women of making such investments, adding a marriage-market cost to the personal utility cost of lower fertility. If this marriage-market penalty shifts, the appeal of career investments, and thus the number of women seeking higher education, may also shift.

The non-assortative equilibrium match predicted by the model is of particular interest because it may also be non-*monotonic* in income, a unique feature mirrored by historical marriage data. In the non-monotonic equilibrium, some portion of richer men match with richer women, but the *richest* men, who have enough of their own income, prefer poorer women. I demonstrate that under two conditions on the surplus produced by marriage—super-modularity in incomes and a decreasing marginal rate of substitution between income and fecundity—it is possible to find parameter values that support such a non-monotonic stable match. This violation of *both* positive assortative matching and negative assortative matching appears in US Census data for women from the 1920–1950 birth cohorts. Among these women, those with college degrees marry wealthier spouses than those with high school degrees or some college only, as expected in an assortative matching framework. However, women with post-bachelors education match with *poorer* spouses than those with college degrees.

In more recent cohorts, the fate of educated women on the marriage market has improved. The model's comparative statics provide insight into potential drivers of this shift. In the model, the impact of career investments on marriage market outcomes depends on the income gained from investment compared to the resulting loss of fertility. When career investments yield small income gains or large fertility losses, equilibrium matches are non-assortative for highly skilled women. By contrast, if the labor market return on investment rises or the fertility cost falls sufficiently, the highest-earning women may be able to compensate their partners for foregone fertility, and thus match assortatively. Using US Population Census data, I show that matching patterns in the US are consistent with these predictions. As returns to career investment for women have risen and desired family sizes—and thus the cost of delaying fertility—have fallen, women with post-bachelors education have matched with richer husbands, surpassing women with college degrees. Rate of marriage for these women has also risen, while divorce rate has fallen. I demonstrate that these changes in educated women's marriage outcomes have been driven entirely by women with *post-bachelors* education, who are most likely to experience a tradeoff between income and reproductive capital from their investment.

These results may also help to explain the dramatic rise in the rates of women seeking higher education in recent years. If the marriage market has transitioned from a non-assortative matching equilibrium to an assortative one, the marriage market cost of making time-consuming career investments has fallen. This partial elimination of the marriage-market penalty associated with post-college education may have amplified the effects of the increase in labor market returns to education. Thus, this model provides an underlying mechanism for an increasing marriage market return to education for women, which Chiappori, Iyigun, and Weiss (2009) find is necessary to explain why schooling rates have increased differentially for women despite increasing returns to education benefiting both women and men.

The model's results rely on men taking into account a woman's expected fertility when considering her suitability as a partner. I test for evidence of this mechanism through an online experiment where ages are randomly assigned to dating profiles, thus controlling for other factors that change with age, such as beauty. Participants rating the hypothetical profiles were incentivized to provide honest responses through the experiment's compensation. In exchange for participating in the study, they received professional dating advice on how to optimize their own online profiles, which was customized based on their ratings in the study. I find that not only do men uniquely have a preference for younger partners, but that this preference is driven by men who have reason to care about fertility and the required knowledge to connect age variation to changes in fertility. Men who already have children, or who believe that female fertility only starts to decline after age 45 (whereas ages in the experiment only vary from 30 to 40), show no preference for partner age. By comparing the impact of an additional year of (randomly assigned) age to the impact of an additional dollar of income, I derive the dating market "price" of the biological clock: a woman who is one year older must make an additional $7000 for her potential partner to be indifferent.

This research contributes to an understanding of the broader consequences of differential reproductive decline between men and women, and how this biological fact may contribute to social trends. The model purposely abstracts away from gender-specific preferences for mates, instead examining whether reproductive capital alone can produce patterns similar to those seen in observational data. I provide experimental evidence that "reproductive capital" is valued not only by women themselves, but also by the marriage market. The model shows the broader consequences of this connection, with the fertility loss from investment affecting marriage market outcomes for educated women, and thus the total return to educational investment. The model's predicted equilibrium responds to underlying factors, such as the labor market return to education, the ability to have children later in life, and flexibility in combining family and career. Thus, individuals, policymakers, and firms may be able to use a better understanding of this tradeoff to blunt the impact of reproductive capital's decline.

Section 2 of this paper reviews related research, Section 3 develops the model, Section 4 compares the model's predicted patterns to US Census data, Section 5 presents the results of the online experiment, and Section 6 concludes.

2 Related Literature

The findings of the model, Census data analysis, and experiment contribute to the literatures on fertility and marriage, work and family tradeoffs, and spousal matching patterns over time.

The idea that fertility may have market value has been introduced in economics literature previously (e.g., Edlund, 2006, and Grossbard-Shechtman, 1985), but not linked to a model of marriage market matching. Edlund argues that the institution of marriage is designed to transfer parental rights from wife to husband, and that wives receive economic transfers in return. There is also work showing that payments for marriage (Arunchalam and Naidu, 2010) and forgoing marriage (i.e., sex work, Edlund and Korn, 2002, Edlund et al., 2009) may be connected to fertility. The market value of fertility is taken as a given in other disciplines, such as evolutionary biology (Trivers, 1972), anthropology (Bell and Song, 1994), and sociology (Hakim, 2010). This paper contributes theoretically and empirically to this literature by providing one potential model in which marital transfers are tied to fertility as an equilibrium result, and then providing well-identified, experimental evidence of men's interest in potential partners being connected to fertility.

In the theoretical literature, some marriage market models have started from the premise that older women are less desirable on the marriage market, while this paper develops a model that provides foundations for this assumption. Siow (1998) considers the impact of fecundity limits on marriage and relative wages, through a model where women do not have the option to remarry later in life due to infertility. Women thus have less motivation to make career investments early in life, since they cannot hope to attract a secondary spouse post divorce, unlike men. Dessy and Djebbari (2010) incorporate this restriction on older women's marriage success into a coordination game regarding optimal marriage timing among women. Mazzocco and Bronson (2013) develop a search model of the marriage market under the restriction that women can only marry when young. This results in variation of the marriage market gender ratio when cohort size changes, and predicting fluctuations in marriage rates that match historical data. In contrast to this earlier work, this paper provides a formal model of the mechanism through which age can affect women's marriage market outcomes, thus offering micro-foundations for the assumption that older women face difficulty marrying.

This paper also introduces another element: the connection between human capital decisions and the "ticking clock" of fecundity. If one's reproductive capacity has economic value, but only for a limited time, then using this time for other purposes is costly. Therefore, career investments that might produce their own economic benefits could carry with them a sufficiently steep cost that women would avoid them.[2] The literature on the link between fertility and career has generally considered the problem of too much fertility, rather than too little. If children are an unavoidable byproduct of being sexually active (due to lack of contraception access), women may be hampered in pursuing greater education and career opportunities (Michael and Willis, 1976). Goldin and Katz (2002) as well as Bailey (2006) and Bailey et al. (2012) examine how the introduction of oral contraceptives enabled women to control their fertility and thus make larger career investments, increasing female education and labor supply and reducing the gender wage gap. Adda, Dustmann, and Stevens (2011) quantify the cost of children in terms of lost wages to women, which they find explains a large portion of the gender wage gap. Buckles (2012), by contrast, examines the impact of fertility limitations, arguing that later-life biological limits on fecundity may restrict women's career participation. She shows that increased access to fertility treatments is related to increased fertility and, marginally, increased labor force participation and higher wages for women over 35. This paper incorporates this tradeoff between career investments and delayed fertility into a model

[2]Perhaps because of this connection, the relationship between age-at-marriage and spousal income is especially apparent for college-educated women, as shown in Appendix Figure 16. These women realize the greatest gain in spousal income by waiting until their late twenties or early thirties to marry, due to either selection or marriage market returns to human capital accumulation, but also show the biggest drop-offs in spousal income for marriages after 30. This indicates that reproductive capital may be especially salient for those with the most to gain from making large career investments.

that provides predictions for matching patterns and investment.

This work also fits with literature linking the increase in women seeking higher education over time to a concurrent improvement in marriage market outcomes for these women (Chiappori, Iyigun and Weiss, 2009; Ge, 2011; Chiappori, Salanié, and Weiss, 2012). My work helps explain the underlying reason for an increase in the marriage market premium for education, in the partial elimination of the penalty associated with lower reproductive capital (due to increased income for highly educated women and a fall in desired family size). Changing marriage patterns for educated women have been noted in recent work, which has in particular documented a rise in marriage rates, and fall in divorce rates, for women with post-college education (Stevenson and Isen, 2010). I distinguish between women with bachelor degrees and women with post-bachelors education, and show that these trends have been driven by only the highly educated women, indicating that the time-cost of education is a key factor. This paper additionally fits with other literature looking at how men and women value different characteristics on the dating and marriage markets (Fisman et al., 2006; Hitsch, Hortaçsu, and Ariely, 2010; Bertrand, Pan, and Kamenica, 2013) and how social forces may drive the degree of assortativeness in mating (Hurder, 2013; Guner et al., 2012; Fernandez, Guner, and Knowles, 2005; Mare and Schwartz, 2005).

Finally, the model I develop provides an interesting application of an anomalous bi-dimensional matching pattern, in which matching is non-monotonic along a single dimension (here, income). Because the matching model I present is truly bi-dimensional, it allows for matches that are not simply either assortative or negative-assortative along a "quality index." Matching models that look at two or more characteristics often reduce these characteristics to an index of overall desirability (e.g, Chiappori et al., 2012). However, if the value of either characteristic varies with the quantity of the other characteristic, the dimensions of the model cannot be collapsed. An example of this is Chiappori et al. (2010), where smokers do not mind if their partners smoke, whereas non-smokers do, and thus no universal index of desirability can be found. Galichon and Salanié (2012) offer a multi-factor example. This type of model is an emerging strand of the literature, and equilibrium characteristics in this setting have only recently been explored. The model I develop also allows the woman's two characteristics to be endogenously chosen, with one affecting the other: she can choose to improve her income only at the expense of reproductive capital. I provide general conditions under which this setting—one side of the market being heterogeneous in two negatively correlated characteristics–can result in non-monotonic matching.

3 A Model of the Marriage Market

This section develops a transferable utility matching model to study the tradeoff between human capital investment and reproductive capital depreciation. I first describe the setup of the model and then characterize the stable equilibrium using a simple example. I then provide general conditions under which a non-monotonic equilibrium can appear. Finally, I discuss how this marriage market equilibrium will affect women's human capital investments, and provide empirical predictions to be compared with Census data.

The model is based on the simple assumption that some kinds of income-increasing career investments require women to delay marriage and childbearing. Thus, in addition to being heterogeneous in income, women are also heterogeneous in fecundity: those that make career investments have higher earnings, but lower reproductive capital. With standard utility functions that include both private consumption and children, this model can predict non-assortative matching at the top of the income distribution. If the loss of fertility is large enough relative to the return to women's career investments, there exists a stable equilibrium where the very highest-income women match with lower-income men than a segment of poorer, but more fertile women. This matching outcome is generalizable to surplus functions where the value of marrying a high-earning women is greater for a high-earning man (super-modularity), but the value of a gain in fertility *relative* to a gain in income is also greater for a high-earning man (a marginal rate of substitution between fertility and income that decreases in income).

The fact that men take reproductive capital into account when choosing a partner adds a marriage-market cost to the personal cost of lowered fertility resulting from time-costly career investments. This can thus reduce women's willingness to invest in human capital. But, the model also predicts that as women's incomes grow, and the fertility penalty from investment falls, high-earning women can compensate their spouses for their lower fertility, and matching will be purely assortative on income. Lower fertility is still costly, as women must make transfers to their husbands to "make up" for foregone fertility, but the lower marriage-market penalty may increase women's willingness to seek higher education and other human capital investments.

Instead of making the assumption that fertility impacts matching and intra-household transfers, the model I present yields this as an equilibrium result, stemming from a driving mechanism, that I will later test, of fertility entering the utility of men evaluating different matches. Transferable utility matching models (Shapley and Shubik, 1971, and Becker, 1973) derive matching patterns from the efficient division and creation of surplus. The equilibrium payoff of each individual in a marriage is *set by the market* as "offers" where both spouses are able to attract one another. These payoff shares essentially act as prices based on the contribution of an individual's traits to the joint surplus and the scarcity of those traits on the market. Thus, a model with simple assumptions only about the form of the utility function can generate rich predictions about matching patterns and transfer flows related to women's level of reproductive capital. Here, the complementarity between fertility and income creates the potential for a non-monotonic match along income. I provide general conditions under which this type of match can occur, which has applications outside the specific question of fertility's role on the marriage market.

3.1 Cobb-Douglas, uniform example

In this model, career investments yield earnings gains, but delay marriage and childbearing, creating a choice for women between going on the marriage market with high income and low fertility (richer and older) or with low income and high fertility (poorer and younger). This feature of the model is intended to capture the impact of large, lumpy career investments such as completing medical school and a residency, pursuing partnership at a law firm, or completing a PhD.

This model has four stages: 1) Women invest in careers; 2) Couples match; 3) The couple has a child with probability π; 4) The couple allocates income between private consumption and their child (a public good).

I begin with a simple example where utilities are Cobb-Douglas and the distribution of men and women is uniform, to allow for clean exposition of theoretical results and graphical representations. The following section discusses the generalizability of these findings.

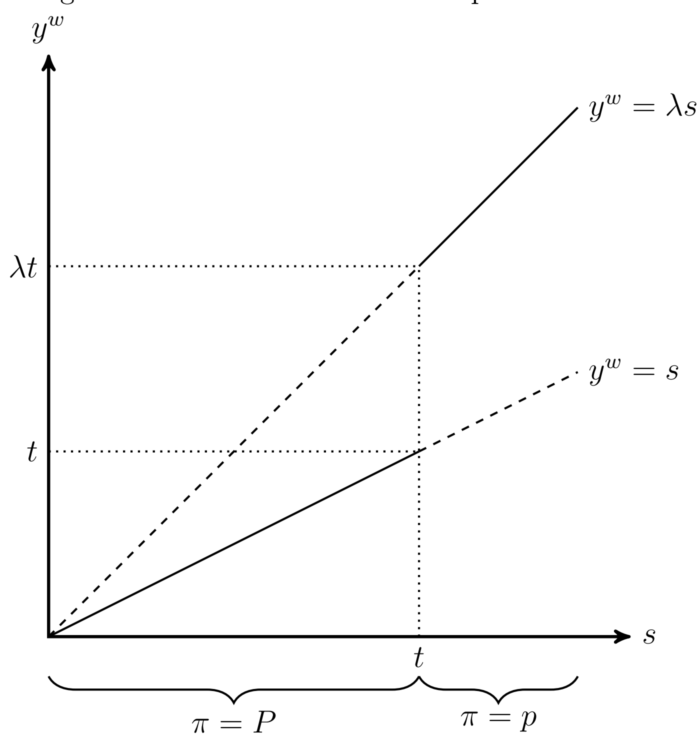
Men and women are each endowed with skill, s. In the man's case, human capital investment is costless, and he therefore arrives on the marriage market with a single characteristic, income y^h, distributed uniformly on $[1, Y]$.[3]

[3] Starting at 1 creates a simple illustration where all men want to marry, because marriage is only "profitable" if

Women, starting with skill s distributed uniformly on $[0, S]$, can also choose to improve their level of income, but doing so takes time, and this time is costly in terms of reproductive capital depreciation. As a result, if they choose to make investments, they will have a lower probability of becoming pregnant when they get married. Women are therefore characterized by a pair of characteristics, (y^w, π). This pair is equal to (s, P) if the woman marries without investing or $(\lambda s, p)$ if the woman marries after investing, where $\lambda > 1$ and $P > p$. Note that the "fertility penalty" of investment is the same for all women, whereas the wage difference from investment increases with skill. Thus, higher skilled women have more to gain from investing.

To begin, I assume there is an exogenously given skill threshold t, above which women invest. After determining the equilibrium in the marriage market conditional on t, I use this equilibrium to solve backwards for which women would optimally invest in the first stage. Thus, assume women with $s > t$ invest and earn income of λs and have fertility p, whereas women with $s < t$ earn income s and have fertility P, as shown in Figure 3.

Figure 3: Women's income versus potential income



total income is greater than 1.

To solve the remainder of the model, we work backwards from consumption decisions if a child occurs, to the surplus function from marriage, to then determine the shape of the match. Married couples can spend income on private consumption given by q^h and q^w and a public good, investment in children, denoted by Q. If individuals do not marry, only private consumption is available. Let the utility of each be given by the Cobb-Douglas functions:

$$u^h(q^h, Q) = q^h(Q+1)$$
$$u^w(q^w, Q) = q^w(Q+1)$$

With budget constraint $q^h + q^w + Q = y^h + y^w$

These utilities satisfy the Bergstrom-Cornes property for transferable utility (Chiappori et al., 2007, Bergstrom and Cornes, 1983), and thus consumption decisions can be found by maximizing the sum of utilities, subject to the budget constraint. Assuming $y^h + y^w > 1$:

$$q^* = \frac{y^h + y^w + 1}{2}$$
$$Q^* = \frac{y^h + y^w - 1}{2}$$

The joint expected utility from marriage, T, is a weighted average between the optimal joint utility if a child is born and the fallback position of allocating all income to private consumption:

$$T = \pi\frac{(y^h + y^w + 1)^2}{4} + (1-\pi)(y^h + y^w)$$

3.1.1 Finding the stable match

I demonstrate that under some conditions, there exists a stable match where the wealthiest men do not match with the wealthiest women, pairing instead with poorer, younger wives. The existence of this equilibrium depends on the fertility cost of career investments relative to the income gained from such investments.

A matching is defined as a set of probabilities that a given man is matched with a given woman, and value functions for each agent indicating their equilibrium surplus share from the resulting match.

A matching is stable if no matched agent would be better off unmatched, and no two matched individuals would both prefer being matched together to their current pairing. Thus, we require:

$$\begin{aligned}
\forall y^h: &\quad u(y^h) \geq y^h \\
\forall s: &\quad v(y^w(s), \pi(s)) \geq y^w(s) \\
\forall y^h, \forall s: &\quad u(y^h) + v(y^w(s), \pi(s)) \geq T(y^h, y^w(s), \pi(s))
\end{aligned}$$

where $u(y^h) + v(y^w(s), \pi(s)) = T(y^h, y^w(s), \pi(s))$ for individuals matched together.

As shown in Becker (1973), super-modularity of the surplus function yields positive assortativeness in a unidimensional setting. Thus, if the surplus function is super-modular in incomes, then for two women of the same fertility level, the woman with the higher income must be matched with a higher-income man.

But what about women with different fertility levels? To make predictions here, we need to understand how the relative trade-off between fertility and income differs for couples with men of different incomes.

If couples with richer men value fertility less relative to income, then the richest women should be matched with the richest men, and thus matching must always be assortative. But if couples with richer men value fertility more, we cannot say whether there should be assortative matching on income or not. It could be that the value of extra fertility, although increasing in income, never outweighs the value of extra income, which is *also* increasing in income due to super-modularity. Or, it could always outweigh the value of extra income. Or, there could be a switching point, where a man is rich enough that he changes from income being valued more in total surplus to fertility being valued more. Thus non-assortative matching on income is possible for women with different fertility levels, depending on whether the fertility tradeoff is large enough to outweigh the gain from income super-modularity.

For the Cobb-Douglas example, the joint product is super-modular in incomes (here, just convexity in income, since the two incomes enter additively):

$$\frac{\partial^2 T}{\partial y^h \partial y^w} = \frac{\pi}{2} > 0$$

Thus, we should expect assortative matching for women with identical fertility, since the increase of the joint product in one partner's income is increasing in the other partner's income.

To examine how the tradeoff between fertility and income varies with men's income, we can look at how the marginal rate of substitution between the woman's two characteristics is changing in the husband's income.

$$-MRS = -\frac{d\pi}{dy^w} = \frac{\frac{\partial T}{\partial y^w}}{\frac{\partial T}{\partial \pi}} = \frac{\pi \frac{y^h + y^w + 1}{2} + (1 - \pi)}{\frac{(y^h + y^w + 1)^2}{4} - (y^h + y^w)}$$

This is the relative change in surplus from an increase in y^w versus an increase in π This ratio is decreasing in y^h:

$$\frac{\partial(-MRS)}{\partial y^h} = -\frac{2(\pi(y^h + y^w - 1) + 4)}{(y^h + y^w - 1)^3}$$

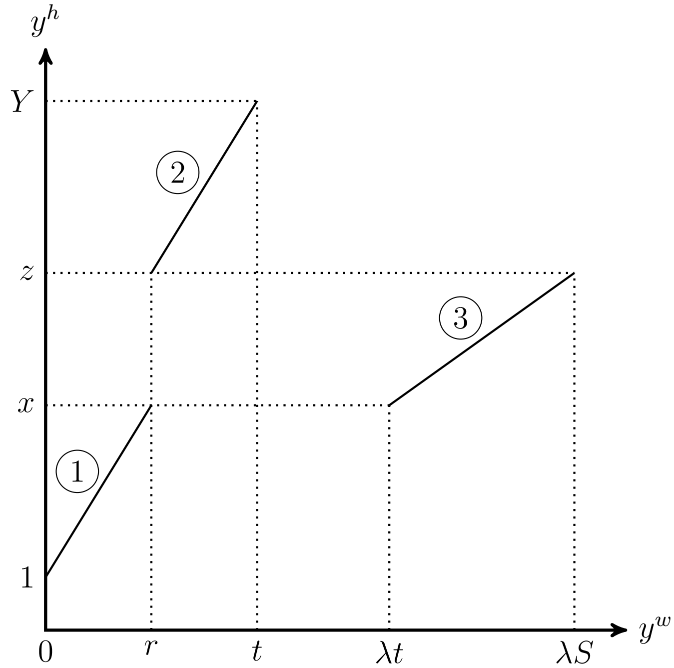
Therefore, the richer the husband is, the less improvement in fertility is required to compensate for income loss. In this sense, couples with richer husbands care more about fertility relative to income, and thus in equilibrium there may be some segment of richer men who actually marry poorer, more fertile women than a segment of poorer men. This condition on the marginal rate of substitution is the crucial ingredient allowing a non-monotonic match in equilibrium.

An equilibrium matching that demonstrates assortative matching for women with the same fertility, but potentially non-assortative matching for women with different fertility, is shown in Figure 4.

Let x and z represent the lower and upper ends of the second segment of men, and r and t represent the lower and upper cutoffs for women. Poor men, from 1 to x, marry low-skill, fertile women (matching assortatively). On the other side of the threshold, the richest group of women matches assortatively with the middle group of men, from x to z. But, the richest men, from z to Y, marry the "best of the rest"—the more high-skilled women among those who have not invested and are thus still fertile.[4]

[4]The matching functions in this uniform case are linear, but in the general case, their form will be determined by

Figure 4: Non-monotonic equilibrium match



This general form allows for the match to be non-monotonic, as depicted, or collapse to positive assortative matching, when $r^* = t$ (and thus segment 2 in Figure 4 has zero mass), or block-negative assortative matching when $r^* = 0$ (and thus segment 1 has zero mass).

By the Becker-Shapley-Shubik result, a match is stable if and only if it solves the total surplus maximization problem for the entire marriage market. Thus, we can easily determine if there is a non-empty set of parameters that yields non-monotonic matching by checking if there is ever an r strictly between 0 and t that solves the surplus maximization problem. The cutoffs x and z can be rewritten in terms of r and t, and as t is fixed before the matching stage, we simply need to find the r^* that maximizes total surplus. If there is an interior solution for r^*, we will have the three-segment, non-monotonic equilibrium. If no such equilibrium exists, then the maximizing r^* will be either t (and the stable match will be positive assortative) or zero (and the stable match will be locally assortative, but negative across the investment threshold).

The stable equilibrium depends on the value of λ, the labor market returns to investment for women, relative to $\frac{P}{p}$, the fertility return to *not* investing, and the size of male incomes. Intuitively,

the distribution so that the number of women above any point on each "segment" exactly matches the number of men above that point.

the maximization process is about finding the optimal threshold, if one exists, for men to "break" from assortative matching—the income that is high enough for the fertility-income complementarity to overwhelm the income-income complementarity. If men are very rich relative to even those women who have invested (and the fertility penalty to investment is large), many men may wish to "break" from their assortative mates, and match with the lower-income, more fertile women. If women earn large salaries post-investment, and the fertility penalty is not too large, it would take a higher male income to justify "breaking" from the assortative match.

Proposition 1. *The maximizing r^*, and thus the form of the stable equilibrium is determined by the value of λ relative to other parameters.*

- *If* $\lambda \leq \frac{S-t}{S+t}(\frac{P}{p}-1)\frac{Y-1}{S}$, *then* $r^* = 0$
- *If* $\frac{S-t}{S+t}(\frac{P}{p}-1)\frac{Y-1}{S} < \lambda < 2\frac{P}{p}\frac{t}{t+S} + (\frac{P}{p}-1)\frac{Y-1}{S}$, *then there is an interior solution for* r^*.
- *If* $\lambda \geq 2\frac{P}{p}\frac{t}{t+S} + (\frac{P}{p}-1)\frac{Y-1}{S}$, *then* $r^* = t$.

The full proof of this proposition is presented in appendix A.1, but I present a sketch of the proof here.

Proof intuition: The joint product of marriage can be written in terms of y and s. To find the total surplus, we need to integrate the joint marital product for each segment across the three segments depicted in Figure 4. To do this, we need to know which y is matched with which s in any equilibrium. Since matching must be assortative on either side of t, the matching function must pair up the lowest-earning women with the lowest-earning man, the next-higher-earning man with the next-higher-earning woman, and so forth. Finding this function allows the writing of s as a function of y. Thus, the total market surplus can be found by integrating the individual pair's surplus as a function of y over all three segments. This is a function of r because the end points for integration and the matching function depend on r.

The total surplus is then maximized with respect to r, over the interval from 0 to t. The total surplus function, is a polynomial of degree 2 in r, with a negative second derivative. This means that if the signs of the first derivative at 0 and t differ, there is a unique interior solution to the maximization problem. If both first derivatives are negative, the maximand is 0, and if both are positive, the maximand is t. This yields the thresholds outlined in the proposition.

Figure 5: Low λ equilibrium match

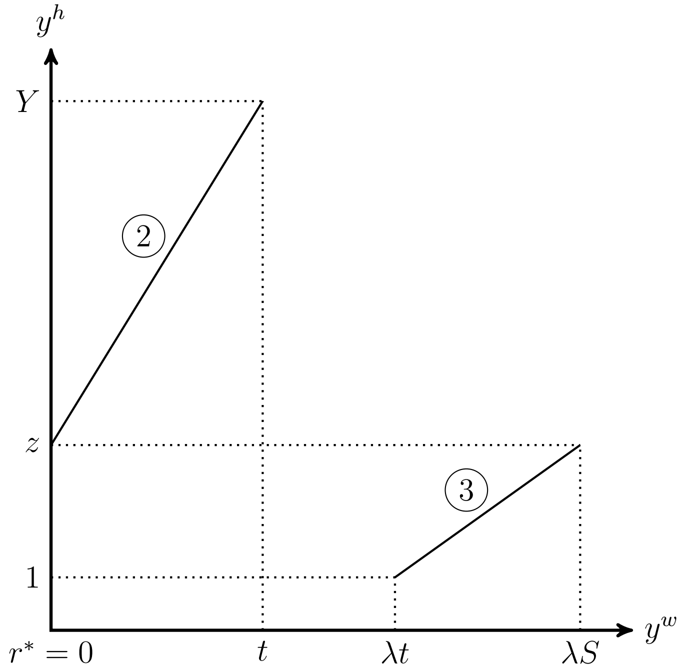
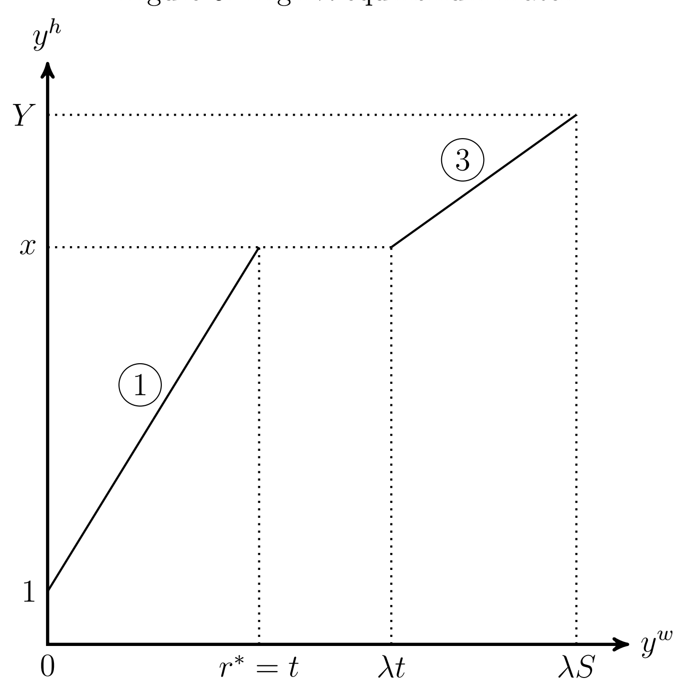


Figure 6: High λ equilibrium match



When $r^* = 0$, then the match will be "block" negative assortative, with two segments only, as shown in Figure 5. When $r^* = t$, then the match will be positive assortative, as shown in Figure 6. When there is an interior solution for r^*, the match will have 3 segments as depicted in Figure 4.

The parameter space for the exact interior solution is non-empty, as $\frac{S-t}{S+t}$ is always less than one and $2\frac{P}{p}\frac{t}{t+S}$ is strictly positive. Thus, the non-monotonic equilibrium can arise whenever the return to investment, λ, is large relative to male income, and the loss of fertility from investment. Said another way, for any value of S, t, P, p, and Y, it is possible to find a λ that will yield non-monotonic matching.

3.1.2 Finding the equilibrium payoffs

Now we can find the payoffs that each agent will get in equilibrium, and hence the share of the surplus captured by each spouse. This is done by using the rule that the sum of each partner's payoffs must equal the total marital product, and that each person chooses his or her spouse to maximize his or her own payoff, under the constraint that the spouse will accept that match.

Let $v_i(s), i \in \{1, 2, 3\}$ represent the value function of a woman of skill s matching in segment i, and $u_i(y), i \in \{1, 2, 3\}$ the value function of a man of income y matching in segment i.

Note that for any individuals of skill s and income y, $u_i(y) + v_i(s) \geq T_i(y, s)$. For married individuals, this holds with equality, and we can solve for the slope of the value function:

$$u_i(y) = Max_s\{T_i(y, s) - v_i(s)\} \Rightarrow v_i'(s) = \frac{\partial T_i(y, s)}{\partial s}$$

and

$$v_i(s) = Max_y\{T_i(y, s) - u_i(y)\} \Rightarrow u_i'(y) = \frac{\partial T_i(y, s)}{\partial y}$$

Through integration, plugging in for y as a function of s, we can identify each value function down to an additive constant. We then use the conditions that $u_1(1) \geq 1$ and $v_1(0) \geq 0$, so that each man and woman agrees to marry, as well as the conditions that a man or woman at a "threshold" between segments must be indifferent to find the constants, and thus derive the value function for each individual.

The appendix shows this process in detail, as well as simulations of the value functions under different parameters.

In a transferable utility matching model, the surplus shares represent "prices" that are assigned based on the value and scarcity of each person's characteristics. The value is determined in terms of contribution to total surplus: Individuals with "good" characteristics generate so much surplus that they can make their partners better off even if they themselves receive high surplus shares. Thus, these individuals' equilibrium "prices," or surplus shares, will be higher.

Interestingly, although the negative assortative matching equilibrium seems much "worse" for women, it is only so because the range of possible returns to investment for which this equilibrium is possible is lower. With that same return to investment available, if women were forced into positively assortative-matched relationships, it would actually be worse for them, because there would be less surplus to distribute.

3.2 General Characterization of Match

The existence of a potentially non-monotonic equilibrium is generalizable to surplus functions exhibiting supermodularity in spouses' incomes and a marginal rate of substitution between income and fertility that decreases in income.

The supermodularity assumption, which is fairly standard in marriage models with children acting as a public good (for example, Lam, 1998), reflects the returns to income being multiplied by the ability to spend additional dollars on both private consumption and investments in children, where enjoyment from children is shared by both husband and wife. In a single dimensional model, this assumption is a good fit for aggregate data, where in general married partners are very similar to one another (although I will document violations of assortativeness in matching in the next section).[5]

The marginal rate of substitution assumption has two intuitive explanations: first, it reflects diminishing marginal returns to income relative to other inputs in the surplus function. Although the surplus is super-modular in incomes, it is natural that if income is abundant, the value of additional income relative to fertility diminishes. Secondly, it is tied to the growing importance of additional surplus from the public good as the amount spent on the public good rises. If a large amount of the value of additional income is coming from the ability to spend that income on a joint

[5] Appendix A.3.1 puts these assumptions to a very basic test using data from the online experiment described in Section 5, and I find suggestive evidence of both.

child, the couple's surplus will be very sensitive to the probability of being able to conceive in the first place.

Proposition 2. *Assume a population of men, characterized by income $y^h \in (0, Y)$, and a population of women endowed with skill $s \in (0, S)$, characterized by income and fecundity (y^w, π). Due to time-consuming career investments by high-skill women,*

$$(y^w, \pi) = \begin{cases} (s, P), & \text{if } s < t \\ (\lambda s, p), & \text{if } s \geq t \end{cases}$$

For simplicity, assume the populations of men and women are equal, atomless and continuous in y and s, and have outside options such that all prefer to marry. When the surplus function $T(y, \pi)$, where $y = y^w + y^h$, increasing in both arguments, exhibits the following properties:

A1 $\frac{\partial^2 T}{\partial y^w \partial y^h} = \frac{\partial^2 T}{\partial y^2} > 0$ *(supermodularity in both spouses' income, equivalent here to convexity in income)*

A2 $\frac{\partial -MRS}{\partial y} < 0$ *where* $-MRS \equiv \frac{\frac{\partial T}{\partial y}}{\frac{\partial T}{\partial \pi}}$ *(The marginal rate of substitution between fertility and income in the surplus function is decreasing in income, meaning higher-income couples value fertility more relative to income),*

then the stable match has three characteristics:

- *Women with $s < t$ will match positive-assortatively with men with regard to income: if $s < s' < t$, and s is matched with y and s' with y', then $y < y'$. Similarly, women with $s > t$ will match positive-assortatively with men with regard to income*

- *There exist parameter configurations for which some high-earning men can marry a woman with $s < t$, while some lower-earning men marry women with $s > t$, thus matching negative-assortatively with regard to income across t.*

- *If some man who marries a woman with $s < t$ is richer than another who marries a woman with $s > t$, then every man richer than the first also marries a woman with $s < t$.*

To prove this requires four lemmas.

Lemma 1. *There is positive assortative matching between men and women on the sets* $(t, S)\times(0, Y)$ *and* $(0, t) \times (0, Y)$.

Proof. Define $\phi(s) = \{y\}$ such that the probability that y is matched with s is greater than 0

For $(t, S)\times(0, Y)$: Suppose that for two women, each having fertility level π, $s' > s$, and $y \in \phi(s)$ and $y' \in \phi(s')$, with $y > y'$. Because T is convex in total income, $T(\lambda s' + y, \pi) + T(\lambda s + y', \pi) > T(\lambda s' + y', \pi) + T(\lambda s + y, \pi) = u(y) + u(y') + v(s) + v(s')$, given the current matching.

This violates the constraints that $u(y) + v(s') \geq T(\lambda s' + y, \pi)$ and $u(y') + v(s) \geq T(\lambda s + y', p)$. Therefore, $y' \geq y$, and μ exhibits positive assortative matching for all women with the same fertility level, and thus on $(t, S) \times (0, Y)$ and $(0, t) \times (0, Y)$ □

I will now demonstrate that Assumption 2, the marginal rate of substitution condition, is sufficient for non-assortative matching under some parameter values. To do this, I first establish that A2 implies increasing differences in the husband's income of the surplus gain from swapping a high-fertility, low-income wife for a low-fertility, high-income wife.

Lemma 2. $\frac{\frac{\partial T}{\partial y}}{\frac{\partial T}{\partial \pi}} \equiv -MRS$ *decreasing in income implies that* $T(y+\delta, P)-T(y'+\delta, p)$ *is an increasing function of* δ.

This proof is presented in appendix A.1.4. I now turn to the implications for matching across the threshold.

Lemma 3. *If* t, Y, $\frac{P}{p}$, S *and* λ *are such that* $T(t + Y, P) > T(\lambda S + Y, p)$, *there exists* y *and* y', $y < y'$, *such that* $\psi(y') < \psi(y)$ *(non-assortative matching possible for* Y *big enough).*

Proof. Because $T(t + Y, P) > T(\lambda S + Y, p)$, by continuity there exists $s < t$ and $s' > t$ such that $T(s + Y, P) > T(\lambda s' + Y, p)$. Because $\frac{\frac{\partial T}{\partial y}}{\frac{\partial T}{\partial \pi}}$ is monotonically decreasing in income, if $T(s + y', P) > T(\lambda s' + y', p)$, then $T(s + y', P) - T(\lambda s' + y', p) > T(s + y, P) - T(\lambda s' + y, p)$ for $y < y'$.

Now suppose that $\psi(Y) > t > \psi(y)$ for all $y < Y$.

$T(t+Y, P) > T(\lambda S+Y, p)$ and $y < Y \Rightarrow T(s+Y, P)-T(\lambda s'+Y, p) > T(s+y, P)-T(\lambda s'+y, p) \Rightarrow T(s+Y, P)+T(\lambda s'+y, p) > T(s+y, P)+T(\lambda s'+Y, p)$, and thus the total surplus can be increased by exchanging the partners of Y and y, which is a contradiction. Thus $\psi(Y) < \psi(y)$ for some $y < Y$. □

A slightly stronger form of assumption 2, that the marginal rate of substitution goes to zero as y goes to infinity, is sufficient to guarantee that for Y large enough $T(t+Y,P) > T(\lambda S+Y,p)$. But, note that this region will still not always exist, because Y may not be large enough relative to λS and the fertility loss, $\frac{P}{p}-1$.

Finally, I show that if there is non-assortative matching, there is a single "break" from the assortative match.

Lemma 4. *If there exists some $\bar{y}$ with $\psi(\bar{y}) < t < \psi(y)$ for $y < \bar{y}$, then for all $y' > \bar{y}$, $\psi(y') < t$ (single threshold for non-assortative matching).*

Proof. Suppose, to the contrary, that for $y' > \bar{y} > y$, $\psi(\bar{y}) < t < \psi(y)$ but $\psi(y') > t$. Denote $s' = \psi(y')$, $\bar{s} = \psi(\bar{y})$, and $s = \psi(y)$. In order for this match to be surplus maximizing, $T(\bar{s}+\bar{y},P) + T(\lambda s'+y',p) > T(\lambda s'+\bar{y},p) + T(\bar{s}+y',P)$.

However, because $\frac{\frac{\partial T}{\partial y}}{\frac{\partial T}{\partial \pi}}$ is decreasing in income, for $y' > \bar{y}$, $T(\bar{s}+\bar{y},P) - T(\lambda s'+\bar{y},p) < T(\bar{s}+y',P) - T(\lambda s'+y',p)$ (proof in appendix). But then $T(\bar{s}+\bar{y},P) + T(\lambda s'+y',p) < T(\lambda s'+\bar{y},p) + T(\bar{s}+y',P)$, which is a contradiction. Therefore, if any $\bar{y}$ has has $\psi(\bar{y}) < t < \psi(y)$ where $\bar{y} > y$, so must every $y' > \bar{y}$. □

Taken together, these four lemmas demonstrate that the match is of the form stated in Proposition 2. This result provides insight into how the marginal rate of substitution between two characteristics can impact matching in bi-dimensional settings, and is thus applicable to any matching problem where one side of the market is characterized by a single characteristic and the other side is characterized by two negatively correlated characteristics that cannot be summarized by an index.

3.3 Exploring optimal human capital investments

I have now characterized the equilibrium in the matching stage, taking the number of women who invest as given. But what if women take the matching equilibrium into account when deciding whether to invest? Then, in addition to the commonly mentioned personal cost of lowered fertility, women would face a second cost: that of matching with a lower quality partner or compensating a higher quality partner to make up for foregone fertility.

To find the precise impact, I endogenize t, allowing women to choose whether they want to invest or not, given the marriage they will eventually encounter. In order to have a broader range of parameter values that yield an interior solution (rather than all or no women getting educated), I add a small fixed cost of educational investment, c. To simplify this section, I set $Y = 2$, $S = 1$, and $P = 1$, making λ, p, c and, t the only unknowns.

I then find the determinants of the optimal t a by setting $v_3(t) = v_2(t)$ to solve for $t^*(\lambda, c, p)$. Although its functional form is complex, t^* varies with the parameters in expected ways: it is increasing in c, decreasing in λ, and decreasing in p. Meaning, the higher the fixed cost of investment, the higher the skill threshold for pursuing it; the higher the return to investment, the lower the skill threshold; and, the higher the chance of conceiving following investment, the lower the threshold. A higher threshold means fewer women making career investments. A lower threshold means more women making career investments, and this can be spurred by a lower fixed cost of investment, greater returns, or a higher chance of conceiving (e.g., through IVF technology).

Under some parameter values, the optimal t will be either 0 or 1. That is, if the returns to investment or the fertility probability post-investment are very low, no woman will optimally choose to invest. If these parameters are very high, all women will do so. Appendix A.1.5 shows a graphical representation of this calculation, under different parameter values.

Note that the process for finding the payoff function internalizes not just the individual change in utility from a different fertility level, but also any change in the share of surplus received. This reflects the impact of traits on the overall surplus: someone with traits that yield a large surplus will in exchange receive a favorable match with a high surplus share. Someone with less desirable traits will face a less desirable match and a lower surplus share. Thus, when equalizing the payoff between investing and not investing to find the optimal threshold, both the personal cost of lower fertility and the cost to the marital surplus are taken into account. Taking these marriage market consequences into account yields a lower t for a given λ and p than if women needed to consider their own preferences for fertility only, or if matching were somehow irrespective of reproductive capital. Thus, the marriage market adds a "second cost" of investment to women's own valuation of foregone fertility.

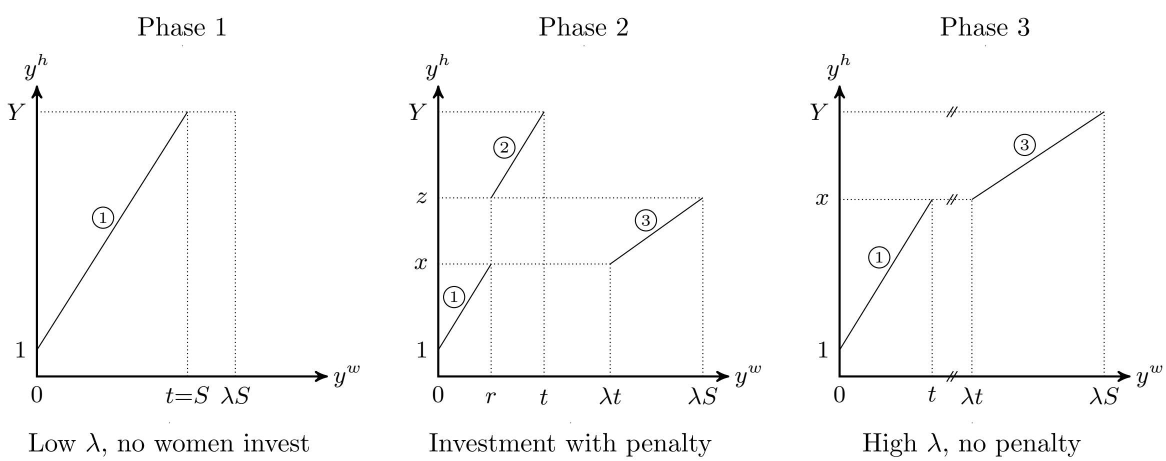
3.4 Model predictions

This section describes the model's predictions for marriage patterns that can be compared to historical data. First, the model predicts that non-monotonic matches should occur when the gain from investment for women is small relative to the fertility loss. Second, it predicts that in an environment with increasing returns to education, falling family sizes, and extended fertility frontiers, matching should move towards assortativeness. Third, the model provides the informal predictions of rising marriage and falling divorce rates for highly educated women.

3.4.1 Matching patterns

The first prediction of the model is that non-monotonic matching is possible, and expected to appear when the return to investment for women is insufficient to compensate comparably skilled men for their foregone fertility. Thus, we expect non-assortative matching at the top of the distribution when men's incomes are large relative to women's, when women gain little from investment (e.g., due to discrimination), when family sizes are large, and when access to fertility treatments and adoption are limited. For low enough λs relative to $\frac{P}{p}$, matching may be completely non-assortative, but in this case, the parameter values are likely to deter investment in the first place. Thus, we expect the middle, non-monotonic equilibrium to be observed, but potentially not the fully block-negative assortative equilibrium. In the non-monotonic equilibrium, the highest skilled women are expected to marry lower-earning men than lower-skilled, and lower-earning, women who have not made career investments.

Figure 7: Potential historical transitions



The model's comparative statics can provide useful predictions for historical shifts. An increase in λ, the returns to education to women, could cause a move between equilibria. If women's earnings increase sufficiently following career investment, they will be able to compensate higher-earning men for their lower fertility, and thus move toward assortative matching with the best men. Interestingly, though, because of the fixed component of the cutoff $\lambda \geq 2\frac{P}{p}\frac{t}{t+S} + (\frac{P}{p} - 1)\frac{Y-1}{S}$, if *both* λ and Y increased simultaneously, the marriage market could shift from the three-segment equilibrium to positive assortative matching. Thus even *general* (non gender-specific) increases in the labor market returns to education could result in an equilibrium shift. I will show in the empirical section that this is consistent with historical evidence since the 1960s: women have gone from being penalized on the marriage market for making human capital investments to being rewarded with better matches, concurrent with an increase in labor market returns to education.

In addition to changing returns to education, assisted reproduction technology could also impact the equilibrium. If p increases, then λ is more likely to exceed both the first and second cutoff. Thus, in-vitro fertilization technology (which increases older women's chances of becoming pregnant), better health and nutrition, better medical insurance, and easier adoption are all likely to push toward more assortative matching regardless of time-intensive career investments.

Falling desired fertility may also lead to a shift toward the assortative matching equilibrium over time: If the total children demanded by a couple is lower, then the fertility cost of a time-consuming investment will be lower, because the chance of being able to successfully achieve a smaller number of children is higher at any given age. The "effective" p is higher when a smaller family is desired.

Combining this with the implications for human capital investments, the model predicts a movement from not very many women making time-costly human capital investments (because the double costs of fertility and the marriage-market response to lower fertility outweigh the gain), to women making these investments but matching non-assortatively, to, finally, assortative matching.

3.4.2 Who marries?

When the popular press laments the plight of educated women on the marriage market, they are often talking about not just *whom* they marry, but *whether* they marry. The model has no formal predictions for who marries (which would require introducing search frictions, or additional heterogenous characteristics, as in Choo and Siow, 2006), but can provide informal intuition for the relative marriage rates between women who invest and those who do not.

Imagine random shocks that cause marriage to be less appealing for some individuals. If these shocks are distributed independently of the endowments of s and y, marriages will be least likely to form (or most likely to break up) where the total surplus is low. In unions with higher surplus, a small shock will be insufficient to derail the match, and thus marriages will only break up (or fail to form) in the case of rarer, larger shocks.

In this model, surplus for individuals who marry (anyone with joint income greater than one) is increasing in the sum of the partner's incomes, for the same fertility level. Thus, when women who have invested match positive-assortatively, the surplus generated by these matches is higher than the surplus generated by matches with high-income women and mid-income men in the three-segment equilibrium. Thus, in a transition from the three-segment equilibrium to the positive-assortative equilibrium, the surplus generated by marriages including the top segment of women grows. This in turn makes these marriages more resilient to shocks, making them more likely to form.

Therefore, over time, marriage rates should increase for women who have made time-costly career investments, relative to other women. Those in higher surplus matches should also divorce less frequently, if the marriage is hit by a shock post-union, and thus divorce rates for highly educated women should also fall.

The next section looks for evidence of these predicted patterns in US Census data.

4 US Census data patterns

This section examines patterns in US Census data relative to the patterns predicted by the model, using women who receive post-bachelors education as a proxy for women who have made potentially fertility-disrupting career investments. I show that, in the cross-section, marriage matches for the 1920–1950 birth cohorts violate *both* positive assortative matching *and* negative assortative matching, with college educated women marrying richer spouses than both women with some college only and women with post-bachelors education. This non-monotonic matching pattern has dissolved in recent cohorts: post-bachelors women now match assortatively with richer men than college women. At the same time, marriage rates have drastically increased and divorce rates fallen for this group.

This reversal in marriage market fortune for educated women has been noted by the literature (e.g., Chiappori, Salanié, and Weiss, 2012, Stevensen and Isen, 2010), but my results show it has been driven by *highly* educated (post-bachelors) women, indicating time-costly investments, and their accompanying fertility cost, may play a role in these societal changes. While there are many potential drivers of these patterns, this section demonstrates that reproductive capital may be a useful complement to existing explanations of marriage outcomes for educated women. In addition to making predictions specifically for highly educated women, the reproductive capital model also has the appealing feature of matching these patterns without requiring gender-specific preferences over partner characteristics.

4.1 Data

This section describes the data and demonstrates that women who receive post-bachelors education (masters, MDs, JDs, PhDs, MBAs, etc.) earn more, marry later, and have fewer children than women with college degrees only, making them a reasonable proxy group for women who make time-consuming career investments. I use 1% samples of US Census data from 1960, 1970, 1980, 1990, 2000, and 2010. In later years, the data comes from the American Community Survey, which continued to contain some demographic questions that were dropped from the decennial population Census.

I restrict my analysis to white individuals in their 40s and 50s, so that the vast majority of first marriage matching activity and educational investments have already taken place by the time they are observed. I analyze each ten-year cohort in a single census year, rather than analyzing multiple groups retrospectively, which allows greater homogeneity of current life situation, since most variables, such as income, are reported for the present time only. In all regressions and figures, I use 41-50 year-old women when age at marriage is not an included variable, and 46-55 year-old women when age at marriage is included, in order to allow for a full range of marriage ages. I restrict to first marriages when showing results for only 1980 and 2010, but use all marriages when showing results across Census years, to allow for comparability with 1990 and 2000 data, which does not contain a variable for marriage number.

Table 1 shows that the model's basic assumption, that there is a tradeoff between career investments, and thus income, and the timing of marriage and childbearing holds true in both 1980 and 2010. I regress total income (in constant 1999 dollars), age at marriage, and children ever born

Table 1: Income, age at marriage, and children versus education (women aged 46-55)

	(1)	(2)	(3)
Dep. variable:	**Total income**	**Age at marr.**	**Children born**
	2010 American Community Survey		
Highly educated	18,027***	0.928***	–
	(387.9)	(0.0717)	
Constant	36,373***	28.31***	–
	(233.6)	(0.0428)	
Observations	56,563	50,815	–
	1980 Population Census		
Highly educated	11,140***	0.468***	-0.467***
	(465.2)	(0.101)	(0.0336)
Constant	21,134***	23.38***	2.623***
	(302.3)	(0.0638)	(0.0218)
Observations	10,907	9,920	10,907

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

(available for 1980 only) on a dummy variable for post-bachelors versus college-only education.[6] Becoming highly educated serves as a reasonable proxy for making time-costly career investments, since college education alone does not interfere with years of fertility, whereas PhDs, medical and law degrees, and MBAs, as well as the career path that comes with them, may. The comparison group of college educated women may contain some women who will make a large career investment, which would attenuate any difference between the groups, but certainly women with graduate degrees are more likely to delay marriage and childbearing, as shown by Table 1.

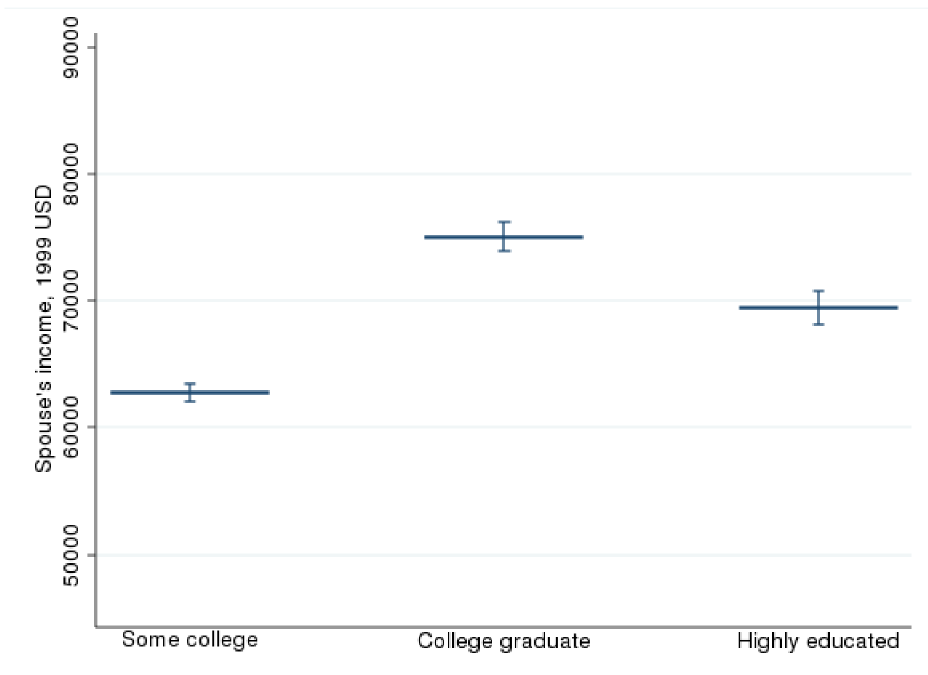
4.2 Non-monotonicity in matching

Census data for women born between 1920 and 1950 shows that marriage matches for this group exhibit the predicted non-monotonicity in matching between male income levels and female education levels (education is preferable to income to describe female "types" because income is chosen endogenously post marriage). In figure 8, women from the 1930–1940 birth cohort (measured when they are 41-50 years old in 1980) who gained a college degree, versus only some college, matched

[6]Children at home, which is available for both years, but is impacted by other factors such as the age of mothers, shows a similar pattern, with highly educated women having fewer children at home in both years, despite likely having children later.

with richer spouses. However, women who went beyond a college degree to receive graduate education matched with poorer spouses than those that stopped at a college degree. This pattern is present as well for the 1920–1930 cohort. For the 1940–1950 cohort, the difference between highly educated and college educated women's spousal incomes is not significant, but the relationship is still non-monotonic, in that spousal income statistically significantly increases for women with a college degree versus some college, but then levels off for women with even higher education. These graphs are shown in the appendix.

Figure 8: Non-monotonicity in spousal income by wife's education level, 41-50 year old women in 1980 Census (1930–1940 birth cohort)



What is the source of this non-monotonicity? The data show that conditional on income, marrying older is always linked to marrying a poorer spouse, as shown in appendix Figure 17. But educational investments change *both* age and income. Because most women do not start childbearing before age 22, and there are still many fertile years left after age 22, even for someone who wants a large family, the reduction in reproductive capital from earning a college degree is expected to be small. Thus, because the women who gain such degrees are more skilled and earn more, they match with higher-income spouses. Women who gain graduate degrees, however, may substantially delay marriage or childbearing, especially since these women may go on to make other career investments.[7]

This distinction is important, as it means that even when there is no apparent marriage-market penalty, in the form of lower matches for educated women, there is still a cost to the loss of reproductive capital—it is simply balanced out by the greater income gained, and thus the woman's ability to sufficiently compensate her spouse.

For the 1920–50 cohort, the loss of reproductive capital outweighed the gain in income on the marriage market. The next section will examine whether later cohorts exhibit the transition to assortative matching predicted by the model.

4.3 Changes over time

Market opportunities for women have risen dramatically in the past 50 years (e.g. Hsieh et al. 2013). Meanwhile, average family size has fallen, with a rapid transition from "four or more" as the modal answer for ideal family size to "two" between 1965 and 1975.[8]

These societal trends correspond in the model to an increase in λ relative to $\frac{P}{p}$, since returns to education at the top of the skill distribution have risen while desired family size has fallen, causing a lower differential between "early start" and "late start" (post-investment) fertility. Thus, we expect a movement from an equilibrium where first no women invest due to the high costs, to a case where some women invest but are "penalized" on the marriage market by matching with lower-income men than women who have not invested, to finally an equilibrium where high-skilled women invest and yet have enough income to compensate their potential mates for their lower fertility, thus matching assortatively.

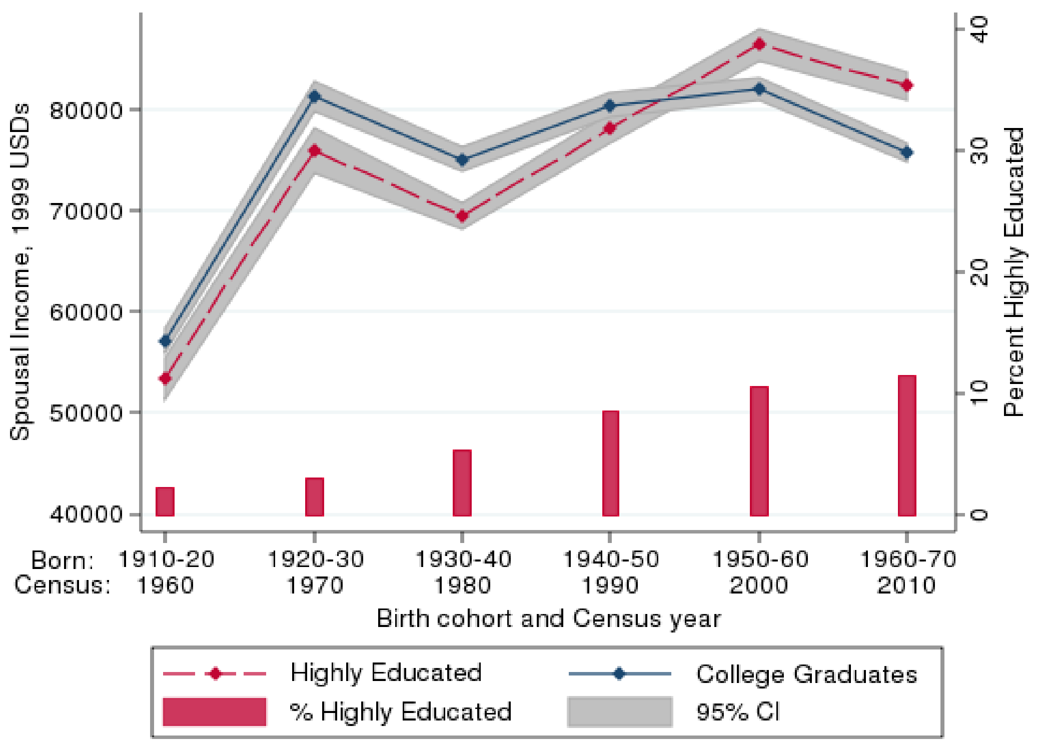
Repeated cross-sections from the US Census align with the comparative statics of the model, as shown in Figure 9. In 1960s, only about 2% of women received education higher than a bachelor degree. By 1980, around 8% of women had achieved post-bachelors education, but these women were matching with men who were poorer than the spouse's of women who stopped at a bachelor degree. Finally, by the 2000s, the highly educated women are matching assortatively with higher-

[7] For example, the natural course of action following law school is to become an associate at a law firm, after med school it is to become a resident, and after an MBA it is to pursue a corporate job. Each of these "paths" represent the type of investment that could delay childbearing.

[8] Pew Center, The new demography of American motherhood, August 2010. See appendix A.2 for graph.

income mates than college-educated women. This is also apparent in a regression with dummies for each cohort, as shown in Table 2.

Figure 9: Spousal income by wife's education level, white women 41-50



As noted earlier, the difference between the college and highly educated groups may be attenuated somewhat by some women in the college-only groups going on to make career investments. Moreover, it could be that highly educated women are unobservably better along some dimension than college educated women, especially those highly educated women who managed to pursue such education at a time when it was rare for women. These two facts make the result of college educated women matching with "better" men at some point all the more striking. It also means, though, that the results in the 2000s may not indicate that we are truly in the third equilibrium phase, but rather only that the "penalty" canceling out the highly educated women's unobservable advantages has been reduced.

It is also important to note that this shift is *not* caused by an underlying shift in how either age at marriage or women's income are treated on the marriage market. A regression comparing the 1980 and 2010 census years (meaning the 1925-35 birth cohort versus the 1955-65 cohort), shown

Table 2: Spousal income by wife's education level, white women 41-50

Dependent variable: Spousal income, 1999 USD			
	(1)	(2)	(3)
Highly educated	-3,809	-4,141*	-4,138*
	(2,355)	(2,354)	(2,354)
1970 × highly	-1,559	-729.4	-722.5
	(3,042)	(3,025)	(3,025)
1980 × highly	-1,775	-1,398	-1,396
	(2,821)	(2,817)	(2,817)
1990 × highly	1,509	1,813	1,810
	(2,580)	(2,579)	(2,579)
2000 × highly	8,099***	8,460***	8,465***
	(2,496)	(2,496)	(2,496)
2010 × highly	10,434***	10,792***	10,793***
	(2,474)	(2,473)	(2,473)
Constant	57,183***	54,232***	56,056***
	(1,224)	(3,948)	(4,627)
Year FEs	Y	Y	Y
YOB FEs		Y	Y
Spouse age			Y
Observations	115,223	115,223	115,223
R-squared	0.007	0.008	0.008

Standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 3: Regression of husband income on wife's income and age at marriage

Dep. variable: **Spousal income**	(1) **1980 census**	(2) **2010 census**
Own income	0.120**	0.153***
	(0.0531)	(0.0130)
Age at marriage	-658.9***	-1,206***
	(202.1)	(122.9)
Constant	79,457***	100,642***
	(6,328)	(3,929)
Observations	1,055	10,936
R-squared	0.013	0.020

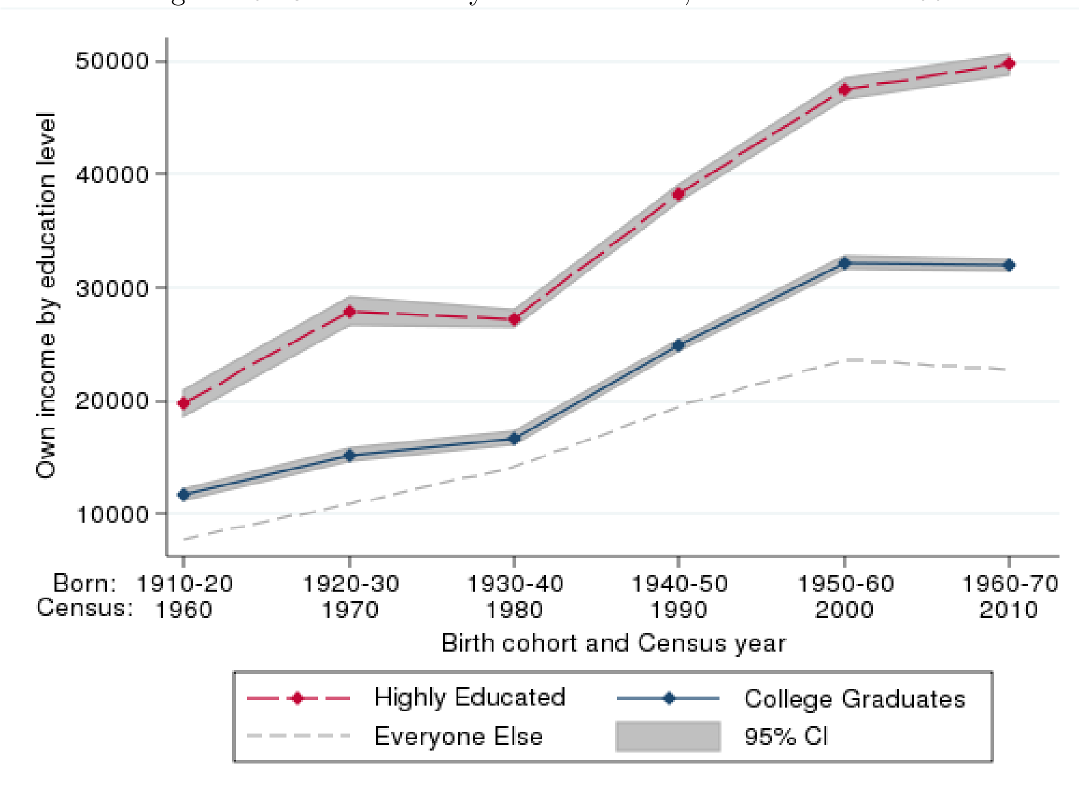
For women who are in the workforce, 45-55 years old
Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

in Table 3, demonstrates that in both years women's own income is correlated with higher spousal income and age is correlated with lower spousal income, when each factor is controlled for. Note, only women with non-zero wage income are used, as otherwise labor supply response to husband's income creates a negative correlation.

These time-invariant relationships between women's characteristics and husbands' incomes support the idea that it is shifts in how these two factors trade off against one another, in terms of how much reproductive capital is lost from career investments and how much income is gained, that has caused the transition to assortative matching for highly educated women, as predicted by the model. Note that the results are also not driven by a crossing in women's own income resulting from the two educational categories—Figure 10 shows that highly educated women's incomes were always higher than college-educated women's incomes.

These patterns are also unlikely to be driven by high-earning women having different tastes for partners. If, potentially, high-earning women prefer lower-earning partners because of either income effects (they are higher earning and thus the marginal benefit of additional income is lower) or a preference for partners who are more likely to be able to spend time at home, it may be possible to recover the initial non-monotonic pattern in matching. (Although, such preferences in traditional models would tend to predict negative assortative matching, since partner income

Figure 10: Own income by education level, white women 41-50



is complementary, rather than non-monotonic matching). However, both of these forces would strengthen, rather than weaken, as female earning power at the top grows, failing to predict the reversal in marriage market outcomes for the "top" women in recent years. Moreover, in Appendix A.3.2, using the experiment described in Section 5, I test for whether male income is less important for high-income women in evaluating potential partners, and find that high-income women actually care *more* about income, in line with the supermodular form of the surplus function used in the model.

One might be concerned that the selection of women into post-bachelors education has changed in a way that could align with the observed matching patterns. For example, if women previously selected into post-bachelors education after receiving a signal that they had a low chance of success on the marriage market, whereas in later years women have sought further education due to having higher marginal career returns.[9] While the current analysis cannot rule out this possibility, I do perform two checks to test the potential magnitude of selection effects. First, I repeat all analyses excluding Hispanic and non-US born women, who make up a larger portion of educated women in later years, and thus may be partially driving differential selection. The results are nearly identical to the graphs presented earlier. I then use data from the National Longitudinal Surveys (NLS) to examine whether there has been an increasing skill premium among women who attain post-bachelors education. If women were previously selecting into post-bachelors education due to negative selection in other areas, they may be expected to be less positively selected on intelligence and academic potential. Table 4 examines this, using data from aptitude scores and educational attainment of three NLS cohorts—the 1968 Young Women panel, the 1979 Youth panel, and the 1997 Youth panel. Unfortunately, the earliest cohort with the necessary test score information only captures the tail end of the negative-assortative matching group, but nonetheless, the trend should be informative about whether there are large shifts occurring in underlying selection factors. These numbers show that there was indeed a large gap in the aptitude between college and highly educated women in the earliest cohort, and that the two numbers are not systematically diverging, which would indicate greater skill-driven selection.

While these analyses provide some information about the potential impact of selection, future

[9] It should be noted that in earlier cohorts, the same selection forces may have applied to college-educated women as well, since college education was still somewhat rare.

Table 4: Relative college and post-bachelors average test score percentiles of three NLS cohorts

	NLS Young Women sample 1944-1954 birth cohort	NLS Youth '79 sample 1957-1964 birth cohort	NLS Youth '97 sample 1980-1984 birth cohort
College graduate	66.5	70.3	63.6
Highly educated	72.0	74.9	69.3

Notes: Numbers represent percentiles compared to other women with the test score information available. Young Women test score data is from the SAT converted into an IQ measurement. 1979 and 1997 data is from the Armed Forces Qualification Test. The difference in percentile at both educational levels between the different years may be attributable to score data being available for a different selection of individuals in different survey rounds (e.g., for the Young Women sample, it was only available for individuals who reached the later years of high school).

research instrumenting for education level would be useful in testing whether the observed changes in marriage-market outcomes are robust to fully controlling for changing selection.

4.4 Marriage and divorce rates

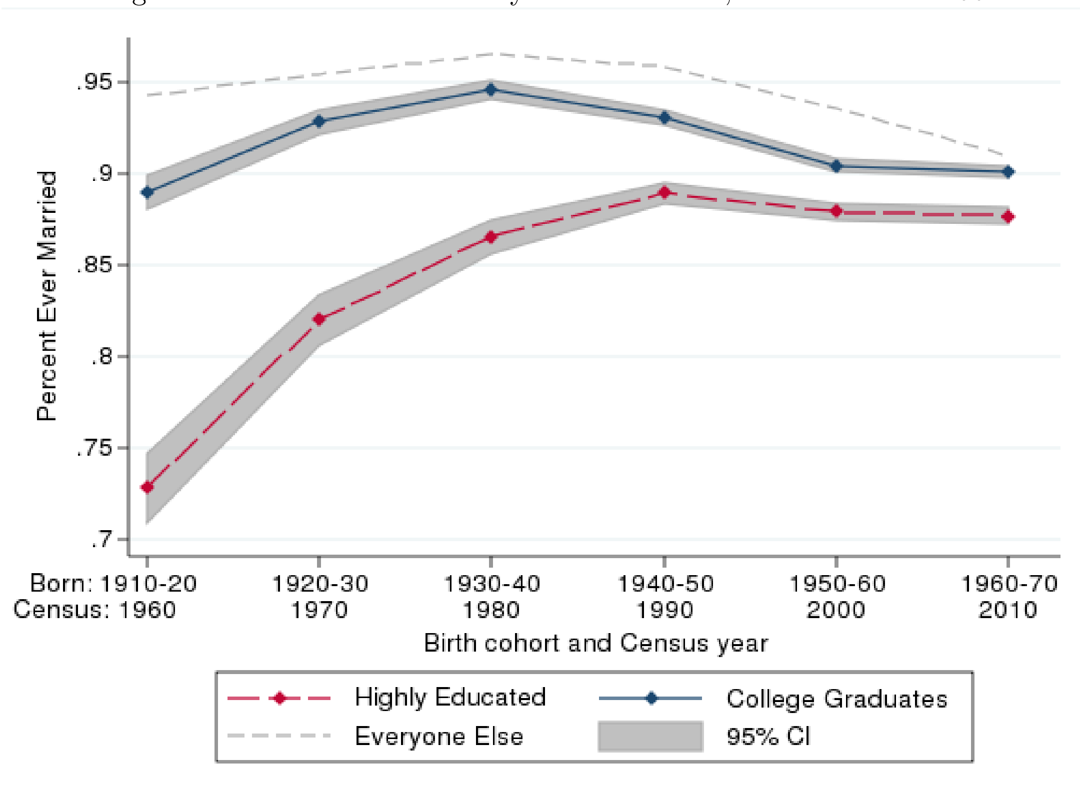
The model's predictions regarding marriage rates also match trends in the data. The model predicts marriage rates for women who make career investments to rise as returns to career investments increase, and matching becomes more assortative in income. This results from the surplus in matches involving the highest-earning women together with the highest-earning men being greater than the surplus with the highest women and mid-level men.

Figure 11 demonstrates this shift in marriage rates for highly educated women. Marriage rates for college educated women closely track marriage rates for less educated women.

Note that these results align with a commonly observed pattern of educated women now being advantaged on the marriage market relative to less educated women (e.g., Stevenson and Isen 2010), whereas previously educated women struggled to find quality mates. However, the graph demonstrates that *highly* educated women are the ones who have made the greatest gains, whereas marriage rates for college educated women (who are usually lumped together with highly educated in the "educated" bucket) have remained relatively flat. Post-bachelors education uniquely requires significant time, and signals future investments requiring even more time, that will delay marriage and child-bearing. Thus, this difference between the two groups points to reproductive capital being an important factor in first the penalization to education on the marriage market and then the later reversal of this penalty as returns to investment have grown.

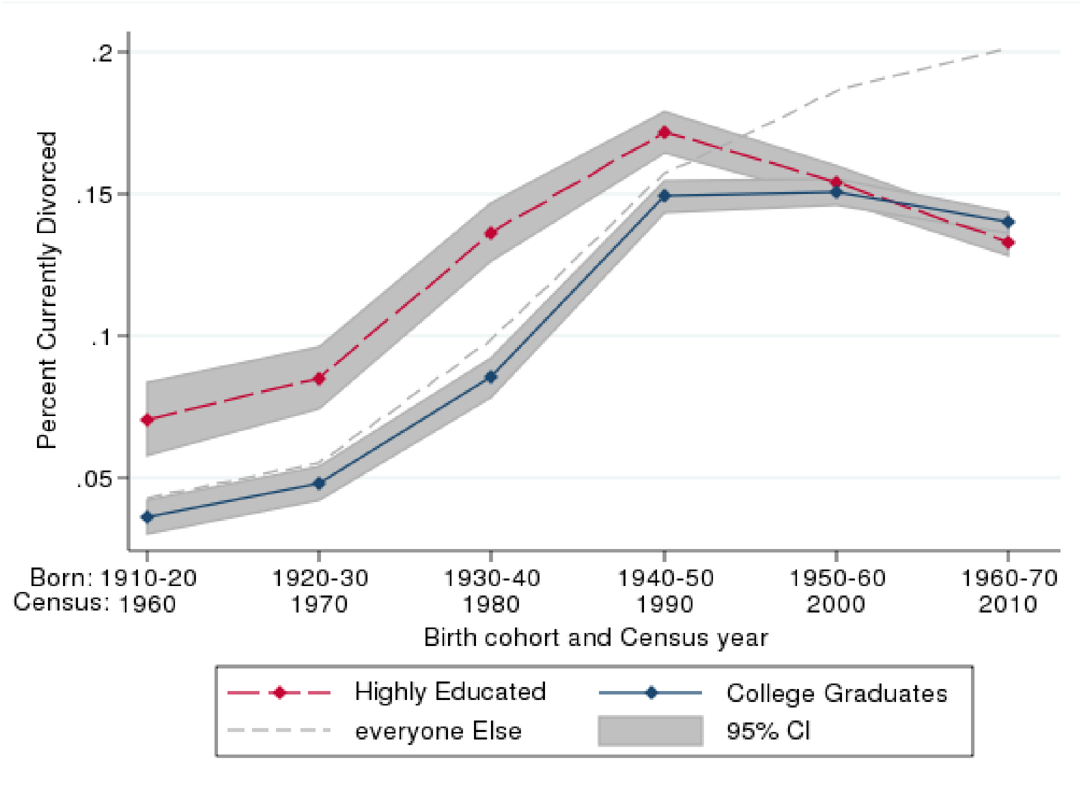
Highly educated women also previously experienced higher divorce rates, consistent with being

Figure 11: Ever married rates by education level, white women 41-50



in a match of lower surplus, and now have comparable divorce rates to college educated women, as shown in figure 12.

Figure 12: Currently divorced rates by education level, white women 41-50



The results presented in this section are consistent with Goldin's (2006) documentation of the "revolution" of women switching from marrying before solidifying their identities to now making pre-marriage investments: once seeking higher education is not penalized in the marriage market, women are more likely to invest before marriage. It is also consistent with the findings of Chiappori, Salanié, and Weiss (2012) that the marriage market return to education has increased steeply for women. In the reproductive capital model, this increase in marital surplus accruing to women with high education results from a decrease in the penalty associated with the age-income tradeoff. Furthermore, the findings documented here match those presented by Rose (2005), who found that the "success gap," the disadvantage faced by successful women on the marriage market, declined from 1980 to 2000.

These analyses show that including reproductive capital into a model of the marriage market allows us to explain both the previously low marriage outcomes for highly educated women and the recent improvements in outcomes for these women on the marriage market. Although the results from the Census show that the matching penalty from seeking higher education has abated, it is important to note that this does not mean that aging is therefore costless to women from more recent cohorts. The results related to education are due to the dual effects of increased income and lower fertility counter-balancing one another. The model predicts that lower fertility *in isolation*, and thus older age, will be penalized on the marriage market no matter the matching regime. The next section uses an online experiment to test for this penalty explicitly, controlling for other factors.

5 Online Experiment

The model suggests a mechanism through which depreciating reproductive capital impacts marriage market outcomes for older women, and thus human capital investments. Men take their partner's expected fertility into account when choosing a mate, and thus higher-income women are not always preferred over lower-income women, since the poorer women may also be younger and more fertile. The evidence presented from US Census shows that the model is consistent with several historical phenomena, including patterns of non-monotonicity in matching and an upswing in marriage "quality" and marriage rates for highly educated women.

The next step is to show evidence of this mechanism acting in a well-identified setting. Do men actively optimize over their partners' expected fertility?

There is a large amount of anecdotal evidence that men prefer younger women on the dating market (e.g., dating website OK Cupid has published data showing that men list their target age ranges as women much younger than themselves, and target their messaging at the younger end of that range).[10] The pattern has also been documented by sociologists England and McClintock (2009), who find that the age gap between spouses is increasing in the man's age at marriage. A 30-year-old man may marry a woman only a couple years younger than himself, whereas a 50-year-old man will, on average, marry a woman ten years younger.

Yet, there is little existing evidence that this preference over age on the marriage market stems from a *conscious* preferences for fertility, rather than evolutionary-induced preferences for age-

[10] OK Trends, "The Case for an Older Woman," February 16th, 2010.

related beauty. Preference for younger looks will also drive a penalty against older women, and hence time-costly career investments, on the marriage market, but the policy implications of a *conscious* preference for fertility versus a beauty-driven preference for youth are different. For example, if a conscious preference for fertility is partly at play, then policies promoting access to assisted reproduction technology could alleviate the marriage-market penalty to delayed marriage, whereas if the preference for youth is exclusively a preference for younger looks, such policies would be ineffective.

To determine whether there is a preference for age, and thus fertility, independent of beauty, I implemented an online experiment in which singles rate profiles of hypothetical partners, with the age randomly assigned while other characteristics, such as the beauty, remained fixed. Income was also randomly assigned to the profiles, providing a measure of the marginal rate of substitution between these two characteristics in partners' preferences.

The results of this online experiment show that men, but not women, rate profiles lower when the randomly assigned age is higher. Moreover, this preference is driven by individuals who currently have no children (as well as desire marriage and children in the future) and have accurate knowledge of the age-fertility tradeoff. This provides evidence that at least some portion of the preference over age on the dating market is driven by a conscious preference for fertility.

5.1 Methodology

The methodology I use isolates age from other factors, while incentivizing participants to give honest responses. The study design is as follows: respondents were recruited online to rate dating profiles, with each respondent rating 40 profiles. All characteristics on these (hypothetical) profiles were fixed, except for age and income, which were randomly assigned as the profile was viewed.

In order for the online experiment data to be valid, subjects must rate the profiles according to their own preferences. However, unlike in most traditional economics experiments, there is no clear way to incentivize self-serving behavior in rating dating profiles. If the profiles were presented as real, in the context of a dating site or speed dating exercise, deception would be involved (since at least some portion of the profile, the exogenously assigned age and income, must be fake). In order to present the profiles as hypothetical while incentivizing honest responses, I used the compensation for participating in the experiment to provide motivation for truthful representation. Participants were offered free customized advice on their own online dating profiles to attract the type of people they had indicated interest in *based on their answers to the experimental questions.* The customized advice was provided by a dating coach hired for this purpose. For the initial sample, this (along with a raffle for free dating site membership, of negligible actuarial value) was the only compensation for participating in the study, so anyone who completed the full experiment must have been motivated by this compensation.

For the initial sample, subjects were recruited using online ads, placed on dating sites or targeted through Google on dating-related keywords. A sample Google ad is shown below:

A Better Dating Profile

Single & 30-40? Take this survey &

get expert dating profile advice!

www.columbiadatingstudy.com

After this initial sample was collected and analyzed, I enlisted the survey firm used as the engine of the online experiment, Qualtrics, to recruit additional respondents in order to test for heterogeneity in effect size among male respondents. These respondents were recruited through Qualtrics' relationship with marketing partners, which offer survey opportunities to their mailing lists in exchange for incentives (e.g., frequent flyer miles, gift certificates). The disadvantage of this study population is that they were motivated by and provided with other incentives in addition to the date coaching (which was still provided). The advantage is that I was able to recruit many more participants more quickly, and strictly require that they fell within demographic parameters and completed the entire survey. The results from this second study support the initial results, and also allow me to test for heterogeneity of the effect based on male characteristics.

To generate the hypothetical dating profiles, I purchased stock photos that were similar in appearance to photos on dating websites and randomly assigned characteristics. I started with 50 photos of men and 50 photos of women, depicting individuals of "ambiguous age," meaning no balding or gray hair, no obvious facial wrinkles, and no overly youthful hairstyles or clothing. I then had 120 undergraduate students rate each photo's physical attractiveness and guess the age of the individual in the photo. Average attractiveness and average "visual age" was then balanced between the men and women, and photos with an average guessed age outside the ages being used for the study were removed.

Using the selected photos, 40 male and 40 female dating profiles were created. The following characteristics were randomly assigned to each dating profile: a username, a height, some interests, and whether they were looking for a serious relationship. The usernames were assigned by using the top 40 names for men and women from the decade of birth for women and men 30-40 years of age, then assigning a random three-digit number. The heights were assigned randomly from a normal distribution using the mean and standard deviation of heights for caucasian men and women. Gender-neutral interests were assigned from a list of top hobbies, with more popular interests being assigned more frequently. All profiles listed the person as "looking for: serious relationship," in order to signal that the rater should consider this person as a potential long-term partner, not a short-term date. Each of these characteristics were assigned to the profile and remain fixed throughout the experiment. Then, as each profile was shown, age and income were randomly assigned: Age between 30 and 40 (inclusive), and an income range from roughly the 25th to 95th percentile for single individuals with at least an associate's degree in the 2010 census.

After agreeing to the consent form, respondents were asked to rate profiles on a scale from 1 to 10. After 10 profiles, the respondents ordered the profiles from most preferred to least preferred, both to break up the monotony of the ranking, and to provide a check for people who are just randomly entering answers without thinking about them (in which case there would be a low correlation between their ratings and rankings). Each individual that completed the survey was shown all 40 profiles. Following this, they completed a brief post-survey including demographic information, dating preferences, and, finally, their knowledge of age-fertility limits for men and women.

The consent form required respondents to certify that "I am between 30 and 40 years old, currently single, and seeking a partner of the opposite gender." However, in the post survey, some initial-sample respondents listed their ages as older than 40 or younger than 30. In the analysis, I exclude these responses. Also, although the profiles feature only white men and women, I did not restrict the race of respondents, so I also exclude non-white respondents during the analysis phase, since cross-racial rankings may be driven by different factors. For the Qualtrics sample, respondents were pre-screened based on race, relationship status, and age.

5.2 Results

The results of the experiment show that men have a preference for younger women, even when physical characteristics are controlled for. Moreover, women exhibit no such preference, indicating that this preference is tied to unique characteristics of aging females. My results further show that fertility is a likely explanation for this preference: men who are not interested in marriage, already have children, or have no knowledge of the age limits of fertility do not exhibit such a preference.

Summary statistics from the data are presented in Table 5, for my target sample of white individuals between 30 and 40.[11] Without these restrictions, in the initial sample 77% of male and 78% of female participants are white, and 74% fall within the targeted age range. In the Qualtrics sample all individuals are white and within the specified age range.

Because the recruitment of additional respondents was motivated by testing for heterogeneity in male responses, male respondents in the Qualtrics sample were enrolled at a 2:1 ratio to female respondents. The oversampled males were also drawn from the higher end of the income distribution, in order to have an income distribution that better mirrors the general population (as Qualtrics respondents, in absence of this sampling concentration, tended to be lower-income, which would not allow for a test of income heterogeneity).

These summary statistics show that men and women taking the survey display similar characteristics, although the men are more likely to be high-income, defined as income over $65,000 per year, in the initial sample—in the Qualtrics sample high-income men were deliberately oversampled. Where men and women differ substantially is their stated preferences for the age of their partner, with men stating on average that the youngest they would date is 26, and the oldest 41, whereas for women this ranges from 33 to 47 in the initial sample. When it comes to their preferred dating range, men look for between 29 and 37, whereas women seek a partner between the ages of 35 and 44. This provides some preliminary evidence that men have differential preferences over their partner's age, compared to women.

The final questions on the survey ask men and women at what age they believe it becomes biologically difficult for each men and women to conceive a child. 100% of initial-sample respondents believe there is a cutoff for women (97% of men and 99% of women in the Qualtrics sample),

[11] I only have birth year, so all birth years where the individual could have been between 30 and 40 when participating were included.

Table 5: Summary Statistics

	Initial Sample			
	Men N=35		**Women N=44**	
Variable	**Mean**	**SD**	**Mean**	**SD**
Age	35.22	3.64	35.84	3.50
High income	.487	.507	.341	.479
College grad	.676	.475	.682	.471
Has kids	.351	.484	.432	.501
Wants (more) kids now	.257	.443	.159	.370
Wants marriage	.460	.505	.432	.501
Date lowest age	25.84	3.57	32.95	3.93
Date highest age	40.84	5.42	46.86	6.92
Preferred low	28.49	3.73	35.30	4.32
Preferred high	37.22	4.55	44.20	6.34
Fem fert cutoff?	1	0	1	0
Fem cutoff age	41.19	6.37	39.67	4.72
Male fert cutoff?	.892	.315	.767	.427
Male cutoff age	53.67	8.91	55.45	8.46

	Qualtrics Sample			
	Men N=207		**Women N=104**	
Variable	**Mean**	**SD**	**Mean**	**SD**
Age	34.65	3.05	34.38	3.21
High income	.387	.488	.159	.363
College grad	.493	.501	.462	.501
Has kids	.203	.403	.423	.496
Wants (more) kids now	.184	.388	.183	.388
Wants marriage	.469	.500	.442	.499
Date lowest age	24.86	4.33	29.97	4.13
Date highest age	41.57	6.09	44.21	7.38
Preferred low	27.03	4.702	32.52	4.38
Preferred high	37.43	5.55	41.34	6.66
Fem fertility cutoff?	.975	.157	.990	.099
Fem cutoff age	43.11	7.11	41.10	6.23
Male fertility cutoff?	.835	.372	.796	.405
Male cutoff age	51.95	9.09	56.55	9.08

indicating that there is some knowledge of differential fertility decline, whereas 89.2% of men and 76.7% of women believe that such a cutoff exists for men. Female respondents put the start of the fertility decline for women somewhat earlier than male respondents, at 39.7 years, versus 41.2. Both male and female respondents, conditional on thinking there *is* a cutoff, believe the cutoff to be higher for men.

I first compare the relationship between individuals' ratings and the randomly assigned ages and incomes for men-rating-women and women-rating-men, using the specification:[12]

$$Rating_{ij} = \beta_0 + \beta_1 age_{ij} + \beta_2 income_{ij} + \alpha_i + \theta_j + u_{ij}$$

Because each individual rates 40 profiles, and each profile is seen by multiple individuals, I can include both rater, α_i, and profile, θ_j, fixed effects.

Table 6 shows this analysis for both the initial sample (panel A) and the Qualtrics sample (panel B). Panel A shows the analysis for all data collected (including incomplete responses) and for those who meet my sample requirements of being between 30 and 40 and white (the considerable data dropped between those specifications is because the complete dataset includes some individuals who did not complete the entire survey, and thus I do not have information on their race or ethnicity). Panel B shows the initial sample of 101 men and 101 women, who were recruited using identical methods, as well as the full sample of 202 men, which includes the over-sampling for high income.

These results show that men rate women lower when the profile is presented with a higher age, whereas women rate men more highly when a higher age is shown. This lower rating is even stronger for white men between the ages of 30 and 40, potentially because restricting in this way excludes individuals who were much older than the targeted age range, and may have less intense age preferences, as well as excluding cross-racial ratings, as all the profiles presented were of white individuals. These results also hold in the Qualtrics sample.

The reduction in rating for an additional year of age is .044 points, on a scale from 1 to 10. Thus, if a woman is 10 years older than another, she will be on average rated 0.4 points lower. A woman who is $10,000 poorer would be rated .06 points lower. To make up for an additional year

[12] I present heteroskedasticity-robust standard errors. Although errors may be correlated within an individual's responses, the "group" status, the individual, is not correlated with the x variable of interest, age, since it is orthogonally assigned within subject's rankings, and thus the criterion for requiring a cluster correction is not met. See: Angrist and Pischke 2009, page 311

Table 6: Age-Rating Relationship for Men vs. Women

Panel A: Initial sample

Dep. variable:	(1)	(2)	(3)	(4)
Profile rating	**Men All**	**Men in Sample**	**Women All**	**Women in Sample**
Age	-0.024**	-0.044***	0.079***	0.131***
	(0.010)	(0.015)	(0.010)	(0.015)
Income ($0,000s)	0.023**	0.061***	0.147***	0.134***
	(0.011)	(0.016)	(0.011)	(0.016)
Constant	5.811***	6.252***	1.074***	-0.080
	(0.467)	(0.662)	(0.409)	(0.658)
Observations	3,752	1,440	4,220	1,800
R-squared	0.487	0.471	0.452	0.394

Panel B: Qualtrics sample

Dep. variable:	(1)	(2)	(3)
Profile rating	**Men**	**Men + oversample**	**Women**
Age	-0.062***	-0.043***	0.028***
	(0.009)	(0.006)	(0.010)
Income ($0,000s)	0.0070	0.032***	0.036***
	(0.009)	(0.007)	(0.010)
Constant	7.475***	9.768***	3.340***
	(0.426)	(0.271)	(0.552)
Observations	4,040	8,080	4,040
R-squared	0.479	0.490	0.463

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

of age, a woman must therefore earn $7,000 more.

The contrasting results for men versus women demonstrate that the negative relationship between a female profile's listed age and the rating cannot be only some kind of lemons effect, where older women still on the market are judged to be less appealing. If this were entirely the channel of this negative preference, women rating men should show a similar aversion to age, although potentially less intense because men marry later. Instead, women show the opposite reaction to age.

Table 7 shows the results for men for several robustness checks. In Panel A, first, I restrict the analysis to only those who completed and submitted the survey, as those who did not may not have been incentivized to provide accurate data, since they did not claim the compensation. Then, I restrict to those who did not opt out of the compensation, which happened in a small number of cases.[13] I next exclude individuals who have a low correlation between their "rate" responses and their "rank" responses, since this may indicate just trying to go through the survey quickly, without regard for the answers. Finally, I exclude those who took the survey during the first two weeks, after which I made a small design change to include a one-second load delay on the photographs, so that individuals would read the profile information more carefully before responding to the photo alone. None of these changes significantly alter the results. In the Qualtrics sample, only the "high correlation" and "no opt out" robustness checks are necessary, and these also do not substantially alter the results.

Table 8 shows two additional specifications that try to control for potential confounders. The first is that photos likely *look* a certain age, and so when these photos are paired with higher ages, the person looks "good for their age," whereas when paired with lower ages the person looks "bad for their age." Because photos that look many different ages are paired with all ages between 30 and 40, the difference between "visual age" and the stated age is separately identified. The visual age was approximated by 120 undergraduate students taking Introduction to Econometrics. When this factor is controlled for, the penalty for higher age is stronger.

The second specification looks at how rater age, and the taste for similarly-aged partners, may affect the relationship between age and ratings. The effect of rater age is not non-parametrically

[13] As the compensation involved the sharing of individual data with a third party, human subjects considerations required I provide the option to opt out.

Table 7: Robustness Checks

Panel A: Initial sample

Dep. variable:	(1)	(2)	(3)	(4)
Profile rating	**Finished**	**No Opt Out**	**High Corr**	**Load Delay**
Age	-0.040**	-0.049***	-0.045***	-0.039**
	(0.018)	(0.016)	(0.016)	(0.017)
Income ($0,000s)	0.067***	0.069***	0.062***	0.061***
	(0.018)	(0.018)	(0.017)	(0.018)
Observations	1,120	1,280	1,360	1,160
R-squared	0.435	0.460	0.465	0.451

Panel B: Qualtrics sample

Dep. variable:	(1)	(2)
Profile rating	**No Opt Out**	**High Corr**
Age	-0.046***	-0.050***
	(0.010)	(0.007)
Income ($0,000s)	0.025**	0.027***
	(0.011)	(0.008)
Observations	3,160	5,600
R-squared	0.489	0.485

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 8: Additional Age Controls

Panel A: Initial sample				
Dep. variable:	(1)	(2)	(3)	(4)
Profile rating	**Base Spec.**	**Visual Age**	**Age Difference**	**"Ideal" Age D.**
Age	-0.043***	-0.171***	-0.044***	-0.038**
	(0.016)	(0.052)	(0.016)	(0.017)
Income ($0,000s)	0.065***	0.065***	0.065***	0.065***
	(0.016)	(0.016)	(0.016)	(0.016)
Visual age - age		-0.129**		
		(0.050)		
(Age diff)^2			-0.001	
			(0.002)	
(Age diff -2)^2				-0.001
				(0.002)
Observations	1,360	1,360	1,360	1,360
R-squared	0.477	0.477	0.478	0.478

Panel B: Qualtrics sample				
Dep. variable:	(1)	(2)	(3)	(4)
Profile rating	**Base Spec.**	**Visual Age**	**Age Difference**	**"Ideal" Age D.**
Age	-0.0427***	-0.093***	-0.040***	-0.024***
	(0.006)	(0.022)	(0.006)	(0.007)
Income ($0,000s)	0.032***	0.032***	0.032***	0.032***
	(0.007)	(0.007)	(0.007)	(0.007)
Visual age - age		-0.050**		
		(0.0214)		
(Age diff)^2			-0.004***	
			(0.001)	
(Age diff -2)^2				-0.004***
				(0.001)
Observations	8,080	8,080	8,080	8,080
R-squared	0.490	0.490	0.491	0.491

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

identified, as the age difference and female age together would be collinear with both male age and female age affecting ratings. For this reason, I use a specification that limits the form to a taste for similarity, column 3, or the taste for similarity with the husband being slightly (two years) older, column 4. There is some evidence of tastes for partner age taking this form (e.g., Hitsch, Hortascu, Ariely, 2010; Choo and Siow, 2006; and Buss, Shackelford, and LeBlanc, 2000). Neither of these additions absorbs men's preference for younger partners. Together, these results suggest that men have a preference for younger partners, even when beauty is controlled for by exogenously assigning age to fixed profiles of potential partners.

Table 9 now tries to test whether this preference for age is really a preference for fertility, and whether some of this preferences operates on a conscious level. Because these regressions look for heterogeneity in the treatment effect based on male characteristics, the initial sample has insufficient size. Thus, these results can be most reliably interpreted in Panel B. Panel B shows that when the profile age is interacted with key rater characteristics—wanting children soon ("Want kids"), not having any children currently ("No kids"), wanting to get married soon ("Want marr"), and knowing that women become less fertile before age 45 ("Knowledge")—the main effect on age becomes smaller, and the interaction term is negative and significant. This shows that men who have more reason to care about fertility—either because they want children soon, do not already have children, are looking for a marriage partner—or greater knowledge of the age-fertility connection have a stronger preference for younger women. In fact, men who already have children (column 4) exhibit no preference over age, with all of the preference being driven by men who currently have no children.

Perhaps the strongest evidence comes from the final column, which interacts age with a knowledge about fertility, defined as a man saying the age that it becomes biologically difficult for women to have children is before 45. For men who lack such knowledge, *there is no preference* over age—the main effect is statistically zero—whereas for the knowledgeable men the negative perception of age is much stronger. The interaction in this final column is also significant in the smaller initial sample.

These results suggest that at least some of the observed preference for younger partners stems from preferences for fertility. If some kind of latent preferences for partner attractiveness as communicated through age were responsible, then whether or not the man wants to have children, or

Table 9: Fertility Mediators

	Panel A: Initial sample				
Dep variable:	(1)	(2)	(3)	(4)	(5)
Profile rating	**Base**	**Marriage**	**Want kids**	**Current kids**	**Knowledge**
Age	-0.043***	-0.051**	-0.028	-0.029	0.014
	(0.016)	(0.020)	(0.018)	(0.028)	(0.025)
Income ($0,000s)	0.065***	0.065***	0.065***	0.065***	0.065***
	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)
Want marr × age		0.017			
		(0.031)			
Want kids × age			-0.051		
			(0.037)		
No kids × age				-0.022	
				(0.034)	
Knowledge × age					-0.078**
					(0.032)
Observations	1,360	1,360	1,360	1,360	1,360
R-squared	0.477	0.477	0.478	0.478	0.479
	Panel B: Qualtrics sample				
Dep variable:	(1)	(2)	(3)	(4)	(5)
Profile rating	**Base**	**Marriage**	**Want kids**	**Current kids**	**Knowledge**
Age	-0.043***	-0.028***	-0.037***	0.002	-0.007
	(0.006)	(0.008)	(0.007)	(0.015)	(0.010)
Income ($0,000s)	0.032***	0.032***	0.032***	0.032***	0.032***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
Want marr × age		-0.032***			
		(0.012)			
Want kids × age			-0.055***		
			(0.017)		
No kids × age				-0.055***	
				(0.016)	
Knowledge × age					-0.057***
					(0.013)
Observations	8,080	8,080	8,080	8,080	7,800
R-squared	0.490	0.490	0.491	0.491	0.488

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

knows about the age-fertility relationship, should have no bearing on the strength of the preference over age. Moreover, this preference appears to be driven by the factors that should be taken into account by a rational, utility-maximizing agent with preferences over fertility. The relative importance of fertility for an individual, and their knowledge of its connection to age, impacts how they respond to age in a potential partner. Thus, instinctive forces connecting age to beauty are not all that are at play, and policies that impact older-age fertility may very well change the costs to aging on the dating market.

Appendix A.3.3 further exploits the individual beliefs about when female fertility starts to decline to look for non-linearity in preferences over age as it relates to fertility. If the preference for age is really a preference for fertility, not all years should be the same: years closer to the fertility decline should affect dating market appeal much more than additional years very far from the fertility decline, or after the fertility decline, when there will be little marginal change to fertility. Appendix table 13 shows that preferences indeed take this shape: additional years close to a rater's perceived fertility cutoff have a much greater impact on rating than age changes more than 10 years before the perceived cutoff or after the cutoff.

Overall, the experiment provides evidence that men do value age independently from beauty, and that this preference appears to be tied to underlying fertility. The experiment also provides an estimate of the monetary valuation of this decline, by comparing the impact of an additional year of age to additional income, finding that a woman must make $7,000 more for her partner to be indifferent to a one-year increase in age.

6 Conclusion

This paper treats women's decisions as a tradeoff between two assets: human capital, which grows based on investment, and reproductive capital, which depreciates with time. The consequences of this tradeoff are examined first through a bi-dimensional matching model and then through an online experiment that provides a "price" for each tick of the biological clock.

The model demonstrates that a small, reasonable set of assumptions can yield non-monotonic matching on income on the marriage market, where the highest-earning women are paired with lower-earning men than poorer, but younger, women. This adds a second cost to women considering time-consuming career investments—not only do they themselves potentially lose out on fertility, but they also must match with lower caliber mates or compensate their partners for this loss as well. This fact is essential to understand why women may make time-consuming career investments at lower rates than men, and also which policies are likely to support greater investments by women. The model can also predict assortative matching when the returns to career investment are sufficiently high compared to the fertility loss from investing.

The model's comparative statics are consistent with patterns in US Census data that I document for the first time: women who received education beyond a bachelor degree previously matched with lower-income men (and married less frequently) than women who only received a college degree. As average family size has fallen and the returns to education have risen, this pattern has reversed, with highly educated women matching assortatively.

To provide evidence for the model's driving mechanism, men optimizing over partners' expected fertilities, I implemented an online dating experiment. The experiment aims to separately identify the age-fertility relationship from other factors, such as beauty, in dating preferences. I show that men, but not women, have preferences over partner age, particularly when they have no children currently and are aware of the age-fertility tradeoff.

"Reproductive capital" is relevant to many issues in business, development economics, and social policy. Firms interested in attracting and retaining top female talent might be able to use a better understanding of reproductive capital to adjust compensation packages to reflect the ever-increasing opportunity cost of career investment as reproductive capital depreciates. This could be realized as greater financial rewards to retain women facing a steep drop-off in marriage market opportunities as they age, or greater flexibility to allow these women to marry and start families while still contributing to the workforce, or provisions to allow women to rejoin the workforce and make time-costly investments once they have already had children. Due to depreciating reproductive capital, optimal contracts for women may be dissimilar to those that have evolved in a historically male-dominated workforce.

Policy-makers could utilize a better understanding of reproductive capital to inform efforts to promote women's human capital accumulation, such as parental leave policies and workforce re-entry programs. Moreover, government policies that ease access to infertility treatments may have spillover impacts on human capital decisions. When viewed through this framework, insurance coverage of infertility treatments becomes a question of not just health policy, but also labor and economic policy. Government policy welfare calculations should consider the impact of policies on both human capital and reproductive capital, and especially the tradeoff between the two.

This work also has implications for social policy addressing older women who are divorced or never married. When reproductive capital is included, these women have less capital at their disposal than younger women with similar human capital attainment. This may explain why older women are more likely to be in poverty than older men. It also implies that policy-makers should consider the impact of declining marriage rates on women's economic well-being (e.g., Edlund and Pande, 2002) as well as the effect of access to paternity rights outside marriage (Rossin-Slater, 2012, shows this decreases marriage rates). This economic model may also help to explain the general social disenfranchisement and marginalization of older women.

A final area where my work can be applied is to the study of international development. Reproductive capital is likely to have an even more profound importance in developing countries where labor market opportunities for women are severely limited. Thus, risks to reproductive capital, such as through childbirth trauma or involuntary sterilization, should be evaluated as economic losses, similar to crop destruction resulting from severe weather. As one example, the study of reproductive capital could provide a way to quantify restitution due to women who have been forcibly sterilized (e.g., Peru, India, and the US). Moreover, the reproductive capital framework can also be applied to examine observed reticence by women in developing countries who report wanting no more children to adopt family planning, particularly long-term forms. Such methods of controlling fertility, while they may better align family size outcomes with a woman's own wishes, threaten one of the few sources of capital not controlled by men.

More broadly, the model demonstrates that the lower are the returns to female skill, due to labor market discrimination or other reasons, the more losses of reproductive capital will limit a woman's overall well-being. This is an important way to assess women's equality in society. If women's access to economic security is entirely dependent on their ability to produce children, reproductive capital is in a sense their only capital. In Zambia, for example, infertile older women have spoken of being outcast from their communities and treated as social pariahs.[14] This research implies we must not only assess women's equality and well-being by how much they have, but also

[14]Focus group discussions conducted by author in October 2011.

by what they could have in the absence of fertility. Reproductive capital could potentially provide a framework for evaluating gender equality on a global level.

Even in more developed countries, the size of the gender wage gap and the time-cost associated with career investments are shown in my model to determine the marriage-market equilibrium, and thus the costs and benefits of human capital investment for women. This section of my research has direct applications to the measurement of global development. Whereas the gender wage gap is often used as a metric of women's empowerment, the time-cost of career investment is rarely considered at the same time. Even if women *can* achieve equal salaries to men, if doing so requires forfeiture of reproductive capital, these women experience a steep penalty. Evaluating concurrently women's labor market opportunities and the reproductive costs of capitalizing on such opportunities provides a more accurate measure of women's economic empowerment.

By framing fertility as an economic asset, and evaluating the tradeoffs its depreciation creates for women, this paper aims to explain historical and contemporary patterns in women's marriage outcomes and human capital investments without resorting to differing preferences as a catch-all.[15] The theoretical and empirical work presented here indicates that reproductive capital's decline may be a useful complement to other explanations of the changing outcomes for educated women on the marriage market, and the growth in rates of women seeking education. Moreover the experimental evidence I present that expected fertility enters male daters' utility functions indicates that the value of this capital is real, and should be taken into account in economic calculus.

[15] Thus heeding Becker-Stigler's (1977) caution to exhaust economic mechanisms before quibbling over tastes.

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A Appendix

A.1 Model

A.1.1 Stable match for Cobb-Douglas uniform example

Proposition 1. *The maximizing r^*, and thus the form of the stable equilibrium is determined by the value of λ relative to other parameters, which falls into one of three regions:*

- *If $\lambda \leq \frac{S-t}{S+t}(\frac{P}{p}-1)\frac{Y-1}{S}$, then $r^*=0$*
- *If $\frac{S-t}{S+t}(\frac{P}{p}-1)\frac{Y-1}{S} < \lambda < 2\frac{P}{p}\frac{t}{t+S}+(\frac{P}{p}-1)\frac{Y-1}{S}$, then there is an interior solution for r^*.*
- *If $\lambda \geq 2\frac{P}{p}\frac{t}{t+S}+(\frac{P}{p}-1)\frac{Y-1}{S}$, then $r^*=t$.*

Proof. Note that the joint product of marriage can be written in terms of y and s:

$$T(y,s)=\begin{cases} \left(\frac{y+s+1}{2}\right)^2 P+(y+s)(1-P) & : s\in[0,t] \\ \left(\frac{y+\lambda s+1}{2}\right)^2 p+(y+\lambda s)(1-p) & : s\in[t,S] \end{cases}$$

To find the total surplus, we need to integrate the joint marital product for each segment across the three segments depicted in Figure 4. To do this, we need to know what y is matched with what s in any equilibrium. Because matching must be assortative on either side of t, the matching function is defined as the function that ensures an exactly equal number of women with income less than some level are matched to the number of men with income less than some level. Along the first segment, the man who has income 1 will be matched with the woman who has income 0, and similarly, the man with income x will be matched with the woman of skill r, and we can use the fact that the density of $r-0$ must equal $x-1$ to solve for s. In the uniform case, this yields a linear matching function between s and y. For example, for segment 1:

$$\begin{aligned} \frac{s}{S} &= \frac{y-1}{Y-1} \\ s &= \frac{y-1}{Y-1}S \\ s &= \frac{S}{Y-1}(y-1) \end{aligned}$$

This can be repeated for all segments, and the resulting functions for s in terms of y plugged in to the surplus function, which is then integrated with respect to y.

$$
\begin{aligned}
H_1(r) &= \int_1^x \left(P\frac{\left(y + \frac{S}{Y-1}(y-1)+1\right)^2}{4} + (1-P)\left(y + \frac{S}{Y-1}(y-1)\right)\right) dy \\
H_2(r) &= \int_z^Y \left(P\frac{\left(y + r + \frac{S}{Y-1}(y-z)+1\right)^2}{4} + (1-P)\left(y + r + \frac{S}{Y-1}(y-z)\right)\right) dy \\
H_3(r) &= \int_x^z \left(p\frac{\left(y + \lambda\left(t + \frac{S}{Y-1}(y-x)\right)+1\right)^2}{4} + (1-p)\left(y + \lambda\left(t + \frac{S}{Y-1}(y-x)\right)\right)\right) dy
\end{aligned}
$$

The sum of these functions, $H = H_1 + H_2 + H_3$, is then maximized with respect to r, over the interval from 0 to t. r appears in the matching functions and also in the limits of integration, since x and z are functions of r. The total surplus function, H, is a polynomial of degree 2 in r, with a negative second derivative. This means that if the signs of the first derivative at 0 and t differ, there is a unique interior solution to the maximization problem. Otherwise the maximand is either 0 or t.

Define $h(r) = \frac{dH(r)}{dr}$

For the interior case, we require $h(0) > 0 > h(t)$

Which gives us:

$$\frac{S-t}{S+t}(\frac{P}{p}-1)\frac{Y-1}{S} < \lambda < 2\frac{P}{p}\frac{t}{t+S} + (\frac{P}{p}-1)\frac{Y-1}{S}$$

If $\lambda \leq \frac{S-t}{S+t}(\frac{P}{p}-1)\frac{Y-1}{S}$, then $h(0) < 0$, and thus the function is decreasing on the entire interval $[0, t]$, and the maximum is reached for $r = 0$

If $\frac{S-t}{S+t}(\frac{P}{p}-1)\frac{Y-1}{S} < \lambda < 2\frac{P}{p}\frac{t}{t+S} + (\frac{P}{p}-1)\frac{Y-1}{S}$, then $h(0) > 0$ and $h(t) < 0$, and thus the max is interior: there exists an $r^* \in [0, t]$ that maximizes the surplus. This exact interior solution is given by:

$$r = \frac{(\frac{P}{p}-1)(t-S) + \frac{S}{Y-1}\lambda(t+S)}{2(\frac{P}{p}-1)) + 2\frac{P}{p}\frac{S}{Y-1}}$$

If $\lambda \geq 2\frac{P}{p}\frac{t}{t+S} + (\frac{P}{p}-1)\frac{Y-1}{S}$, then $h(t) > 0$, and thus the function is increasing on the entire interval $[0,t]$, and the maximum is reached for $r=t$. $\square$

A.1.2 Finding the payoff functions

For notational simplicity, let's define $\theta \equiv \frac{S}{Y-1}$.

Recall the matching function for the first segment, with

$$y = \frac{1}{\theta}s + 1$$
$$s = \theta(y-1)$$

And the surplus function:

$$T_1(y,s) = \left(\frac{y+s+1}{2}\right)^2 P + (y+s)(1-P)$$

Through the above maximization procedure, we can then determine the value function, plugging in for y as a function of s, and s as a function of y.

$$\begin{aligned}
u_1\prime(y) &= (y+s+1)\frac{P}{2} + (1-P) \\
&= (y+\theta(y-1)+1)\frac{P}{2} + (1-P) \\
u_1(y) &= \int (y+\theta(y-1)+1)\frac{P}{2} + (1-P)\,dy \\
u_1(y) &= \left(\frac{y^2}{2}(1+\theta) + y(1-\theta)\right)\frac{P}{2} + y(1-P) + C_1
\end{aligned}$$

$$\begin{aligned}
v_1\prime(s) &= (y+s+1)\frac{P}{2} + (1-P) \\
&= \left(\frac{1}{\theta}s + 1 + s + 1\right)\frac{P}{2} + (1-P) \\
v_1(s) &= \int \left(\frac{1}{\theta}s + 1 + s + 1\right)\frac{P}{2} + (1-P)\,ds \\
v_1(s) &= \left(\frac{s^2}{2}\left(\frac{1}{\theta}+1\right) + 2s\right)\frac{P}{2} + s(1-P) + K_1
\end{aligned}$$

Note that for two matched individuals, $u(y) + v(s) = T(y,s)$. Thus:

$$
\begin{aligned}
&\left(\frac{y^2}{2}(1+\theta)+y(1-\theta)\right)\frac{P}{2}+y(1-P)+C_1\\
&+\left(\frac{s^2}{2}\left(\frac{1}{\theta}+1\right)+2s\right)\frac{P}{2}+s(1-P)+K_1\\
&=\left(\frac{y+s+1}{2}\right)^2 P+(y+s)(1-P)
\end{aligned}
$$

Plugging in for y:

$$
\begin{aligned}
u_1(\frac{1}{\theta}s+1)+v_1(s) &= T_1(\frac{1}{\theta}s+1,s)\\
\Rightarrow C_1+K_1 &= \frac{1}{4}P(\theta+1)
\end{aligned}
$$

For segment two, the matching function is:

$$
y = z+\frac{1}{\theta}(s-r)
$$

$$
s = r+\theta(y-z)
$$

Following the same maximization and integration procedure, plugging in for y as a function of s, and s as a function of y, and noting that $T_2(y,s)=T_1(y,s)$, we find:

$$
\begin{aligned}
u_2\prime(y) &= (y+s+1)\frac{P}{2} + (1-P) \\
&= (y+r+\theta(y-z)+1)\frac{P}{2} + (1-P) \\
u_2(y) &= \int (y+r+\theta(y-z)+1)\frac{P}{2} + (1-P)\,dy \\
u_2(y) &= \left(\frac{y^2}{2}(1+\theta) + y(1+r-\theta z)\right)\frac{P}{2} + y(1-P) + C_2
\end{aligned}
$$

$$
\begin{aligned}
v_2\prime(s) &= (y+s+1)\frac{P}{2} + (1-P) \\
&= \left(z+\frac{1}{\theta}(s-r)+s+1\right)\frac{P}{2} + (1-P) \\
v_2(s) &= \int \left(z+\frac{1}{\theta}(s-r)+s+1\right)\frac{P}{2} + (1-P)\,ds \\
v_2(s) &= \left(\frac{s^2}{2}\left(\frac{1}{\theta}+1\right) + s(1+z-\frac{1}{\theta}r)\right)\frac{P}{2} + s(1-P) + K_2
\end{aligned}
$$

Again we have the restriction that $u(y)+v(s)=T(y,s)$, yielding:

$$
\begin{aligned}
&\left(\frac{y^2}{2}(1+\theta) + y(1+r-\theta z)\right)\frac{P}{2} + y(1-P) + C_2 \\
+&\left(\frac{s^2}{2}\left(\frac{1}{\theta}+1\right) + s(1+z-\frac{1}{\theta}r)\right)\frac{P}{2} + s(1-P) + K_2 \\
=&\left(\frac{y+s+1}{2}\right)^2 P + (y+s)(1-P)
\end{aligned}
$$

Plugging in for y:

$$
\begin{aligned}
u_2(z+\frac{1}{\theta}(s-r)) + v_2(s) &= T_2(z+\frac{1}{\theta}(s-r), s) \\
\Rightarrow C_2 + K_2 &= \frac{1}{4\theta}\left(Pr^2 - 2Prz\theta + Pz^2\theta^2 + P\theta\right)
\end{aligned}
$$

Plug in for z:

$$
C_2 + K_2 = \frac{1}{4\theta}\left(PY^2\theta^2 - 2PYt\theta + Pt^2 + P\theta\right)
$$

In the final segment, the matching function is:

$$y = x + \frac{1}{\theta}(s-t)$$
$$s = t + \theta(y-x)$$

In this case, the joint product, T_3, has a different form:

$$T_3(y,s) = \left(\frac{y+\lambda s+1}{2}\right)^2 p + (y+\lambda s)\,(1-p)$$

Again maximizing and integrating gives:

$$\begin{aligned}
u_3\prime\,(y) &= (y+\lambda s+1)\,\frac{p}{2} + (1-p) \\
&= (y+\lambda(t+\theta(y-x))+1)\,\frac{p}{2} + (1-p) \\
u_3\,(y) &= \int (y+\lambda(t+\theta(y-x))+1)\,\frac{p}{2} + (1-p)\,dy \\
u_3\,(y) &= \left(\frac{y^2}{2}\,(1+\lambda\theta) + y\,(1+\lambda(t-\theta x))\right)\frac{p}{2} + y\,(1-p) + C_3
\end{aligned}$$

$$\begin{aligned}
v_3\prime\,(s) &= (y+\lambda s+1)\,\frac{\lambda p}{2} + \lambda\,(1-p) \\
&= \left(x + \frac{1}{\theta}(s-t) + \lambda s + 1\right)\frac{\lambda p}{2} + \lambda\,(1-p) \\
v_3\,(s) &= \int \left(x + \frac{1}{\theta}(s-t) + \lambda s + 1\right)\frac{\lambda p}{2} + \lambda\,(1-p)\,ds \\
v_3\,(s) &= \left(\frac{s^2}{2}\left(\frac{1}{\theta}+\lambda\right) + s(1+(x-\frac{1}{\theta}t))\right)\frac{\lambda p}{2} + s\lambda\,(1-p) + K_3
\end{aligned}$$

The restriction that $u(y) + v(s) = T(y,s)$ gives:

$$\begin{aligned}
&\left(\frac{y^2}{2}\,(1+\lambda\theta) + y\,(1+\lambda(t-\theta x))\right)\frac{p}{2} + y\,(1-p) + C_3 \\
&+\left(\frac{s^2}{2}\left(\frac{1}{\theta}+\lambda\right) + s(1+(x-\frac{1}{\theta}t)\right)\frac{\lambda p}{2} + s\lambda\,(1-p) + K_3 \\
&= \left(\frac{y+\lambda s+1}{2}\right)^2 p + (y+\lambda s)\,(1-p)
\end{aligned}$$

Plugging in for y:

$$
\begin{aligned}
& u_3(x+\frac{1}{\theta}(s-t))+v_3(s)=T_3(x+\frac{1}{\theta}(s-t),s) \\
\Rightarrow & C_3+K_3=\frac{1}{4\theta}\left(p\lambda t^2-2p\lambda tx\theta+p\lambda x^2\theta^2+p\theta\right)
\end{aligned}
$$

Plugging in for x:

$$
C_3+K_3=\frac{p}{4\theta}\left(\lambda r^2-2\lambda rt+2\lambda r\theta+\lambda t^2-2\lambda t\theta+\lambda\theta^2+\theta\right)
$$

The constants can then be solved for using the constraints that, in order for the match to be stable, two men with the same income cannot receive different utilities. Thus, the men at all "break points," between two segments, must be indifferent. Additionally, a woman of the same income level must always receive a unique payoff. (For now, we do not restrict that all women of the same skill level must receive the same payoff, since the educational decision was undertaken before entering the marriage market, and cannot be changed).

In particular, $v_1(r)=v_2(r)$ yields a relationship between K_1 and K_2. But, given $K_1=0$, this allows us to solve for $K_2=\frac{1}{2\theta}\left(Pr\theta+Prt-PYr\theta\right)$.

From segment 2, we have $C_2+K_2=\frac{1}{4\theta}\left(PY^2\theta^2-2PYt\theta+Pt^2+P\theta\right)$, which allows us to solve for $C_2=\frac{1}{4}\frac{P}{\theta}\left(\theta+Y^2\theta^2-2r\theta-2rt+t^2+2Yr\theta-2Yt\theta\right)$.

Then $u_2(z)=u_3(z)$ gives us a relationship between C_2 and C_3, which allows us to solve for $C_3+\frac{1}{2}p\left(\left(\lambda\left(t-\theta\left(\frac{r}{\theta}+1\right)\right)+1\right)\left(Y+\frac{1}{\theta}(r-t)\right)+\frac{1}{2}(\theta\lambda+1)\left(Y+\frac{1}{\theta}(r-t)\right)^2\right)-\left(Y+\frac{1}{\theta}(r-t)\right)(p-1)$.

Then, using the relationship from segment 3 between the two constants, we can solve for $K_3=\frac{p}{4\theta}\left(\lambda r^2-2\lambda rt+2\lambda r\theta+\lambda t^2-2\lambda t\theta+\lambda\theta^2+\theta\right)-C_3$.

We then can use $u_1(x)=u_3(x)$ to solve for C_1, which gives us two equations for C_1, which can be used to find r, giving us:

$$
r=\frac{(P-p)(t-\theta(Y-1))+\theta\lambda\left(t+\theta(Y-1)\right)p}{2(P-p))+2P\theta}
$$

which is the same as the equation found through the surplus maximization method. Together with the equations $x=\frac{1}{\theta}r+1$ and $z=Y-\frac{1}{\theta}(t-r)$, we now have eliminated the unknowns from the model.

A.1.3 The form of the payoff functions

These payoffs are strictly increasing in y and s, for men and women respectively, but are not necessarily strictly increasing across segments for women (they are for men). For example, it is possible for the woman with skill $t+\epsilon$ to have a lower payoff than the woman with income $t-\epsilon$, because education choice is taken to be exogenous. We have, however, restricted the payoff of the woman with skill $r+\epsilon$ to be higher than the woman with skill $r-\epsilon$, by making the woman with skill exactly equal to r indifferent, in order for the equilibrium to be stable.

The top two images in figure 13 shows what these payoffs look like for the parameter values $S=1$, $Y=2$, $P=1$, $p=.5$, $\lambda=1.5$, and $t=.7$, while the following series of images shows the impact of perturbing these parameters. A lower p causes the optimal r to fall, and more men to break from assortative mating, making the portion of men the women who have invested match with less attractive. A higher p moves in the opposite direction, with only the very top segment of men breaking from assortative matching. A lower λ causes the women who have invested to have worse utilities at t than those that have not, which would potentially discourage less investment, were t allowed to be endogenous. A higher lambda creates excess payoff for those that have invested. A higher t alters the break points for the matching and utility premiums, but does not greatly alter the payoffs.

Note that for some of these parameter values, the conditions on λ for the three-segment equilibrium to be stable are not satisfied. For example, if p is too high, then $r=t$ is surplus maximizing (with a high chance of pregnancy after investment, there's no reason for men to break from assortative mating), and if p is too low, $r=0$ is optimal.

A.1.4 General from of the match

Lemma 2. *For $T(y,\pi)$ increasing in both arguments, if $\frac{\frac{\partial T}{\partial y}}{\frac{\partial T}{\partial \pi}} \equiv -MRS$ is decreasing in y and $T(x+d,P) > T(x'+d,p)$ for some d and $P>p$, $x'>x$, then for each $\delta > d$, $T(x+\delta,P)-T(x'+\delta,p)$ is an increasing function of δ.*

Proof. Define $z(\delta)$ as the level of income that makes $T(z(\delta)+\delta,p) = T(x+\delta,P) \equiv T_\delta$.

Figure 13: Payoff simulations

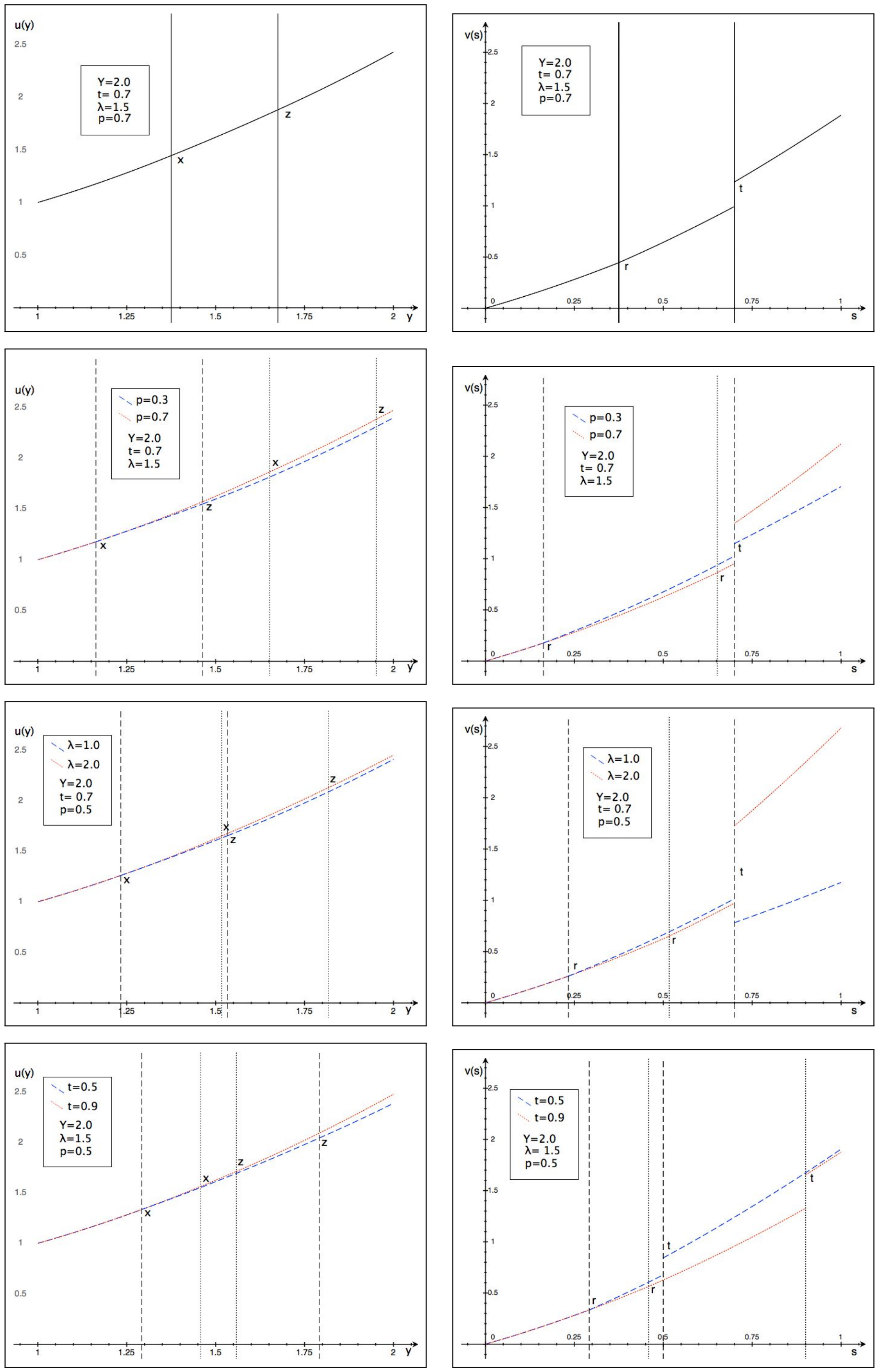
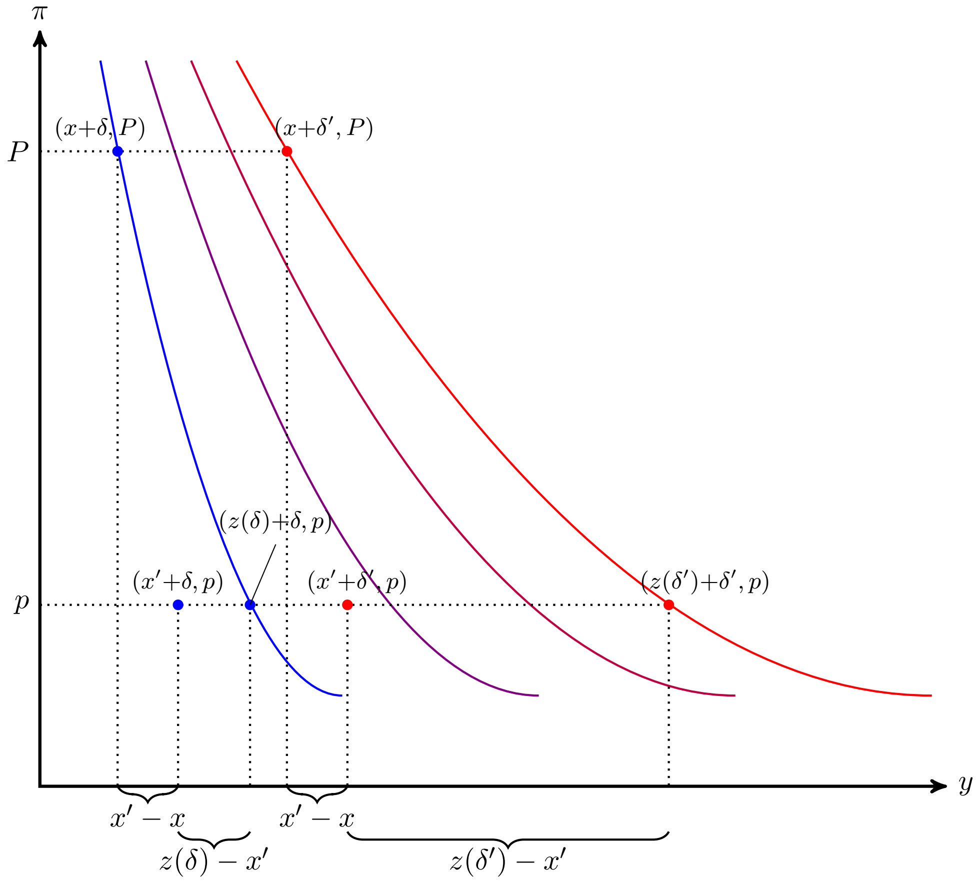


Figure 14: Illustration showing $z(\delta) - x'$ increasing in δ for $-MRS$ decreasing in y



Since $T(z(\delta) + \delta, p) = T(x + \delta, P)$, to prove $T(x + \delta, P) - T(x' + \delta, p)$, we only need show that $T(z(\delta) + \delta, p) - T(x' + \delta, p)$ increasing in δ

To show that $T(z(\delta)+\delta, p)-T(x'+\delta, p)$ is increasing in δ, it is sufficient to show $z(\delta)$ is weakly increasing in δ, since convexity of the surplus in income means that a given loss of y decreases the surplus more for higher y couples:

$$
\begin{aligned}
T(z(\delta) + \delta, p) - T(x' + \delta, p) &= \int_{x'}^{z(\delta)} \frac{\partial T}{\partial y}(y + \delta, p)dy \\
&> (z(\delta) - x')\frac{\partial T}{\partial y}(y + \delta, p)
\end{aligned}
$$

because $\frac{\partial^2 T}{\partial y^2} > 0$. (Note, this is where the assumption that $T(x + d, P) > T(x' + d, p)$, and hence

$T(z(\delta) + \delta, P) > T(x' + \delta, p)$, is required.)

Thus, we need to show that $z(\delta)$ is weakly increasing in δ.

Let $g \in [0,1]$ define the distance traveled from P to p along an iso-surplus curve at level T_δ starting from $(x + \delta, P)$, such that $\pi(g) = P - g(P - p)$, and finishing at $(z(\delta) + \delta, p)$. Note that $\pi(g)$ is independent of δ. At each g, we define $y_\delta(g)$ as the value of y such that $T(y_\delta(g), \pi(g)) = T_\delta$. Then:

$$\frac{\partial T}{\partial y}\frac{\partial y_\delta}{\partial g} + \frac{\partial T}{\partial \pi}\frac{\partial \pi}{\partial g} = 0$$

as we "walk" along the iso-surplus curve.

This implies

$$\frac{\partial y_\delta}{\partial g} = -\frac{\frac{\partial T}{\partial \pi}}{\frac{\partial T}{\partial y}}\frac{\partial \pi}{\partial g}$$

$$\int_0^1 \frac{\partial y_\delta}{\partial g} dg = \int_0^1 \frac{1}{MRS(y_\delta(g), \pi(g))}\frac{\partial \pi}{\partial g} dg$$

$y_\delta(0) = x + \delta$ at the starting point of the T_δ iso-surplus curve. $\frac{\partial \pi}{\partial g}$ can be replaced with the linear function $-(P - p)$. This yields:

$$\begin{aligned} \int_0^1 \frac{\partial y_\delta}{\partial g} dg &= \int_0^1 \frac{1}{MRS(y_\delta(g), \pi(g))}\frac{\partial \pi}{\partial g} dg \\ \Rightarrow z(\delta) + \delta - (x + \delta) &= \int_0^1 -\frac{1}{MRS(y_\delta(g), \pi(g))}(P - p) dg \\ \Rightarrow z(\delta) &= \int_0^1 -\frac{1}{MRS(y_\delta(g), \pi(g))}(P - p) dg + x \end{aligned}$$

I will now show that the righthand side expression is increasing in δ. $\pi(g)$ is constant in δ, by definition. T_δ is strictly increasing in δ, because $T(x + \delta, P)$ is strictly increasing in δ, and $T_\delta \equiv T(x + \delta, P$. Thus, since $\pi(g)$ is constant in δ, $y_\delta(g)$ must be increasing in δ.

The $-MRS$ is decreasing in y, by assumption. Therefore, $-\frac{1}{MRS}$ is increasing in y. As $y_\delta(g)$ is increasing in δ, and $\pi(g)$ is constant, $-\frac{1}{MRS}$ is increasing in δ. Because the expression inside the integral is increasing in δ for each g, the integral must also be increasing in δ, and thus the righthand side expression is increasing in δ.

Then, the lefthand side must also be increasing, meaning $z(\delta)$ is increasing in δ. $z(\delta)$ increasing in δ implies:

$$T(z(\delta)+\delta,p)-T(x'+\delta,p) \text{ increasing in } \delta$$
$$\Rightarrow T(x+\delta,P)-T(x'+\delta,p) \text{ increasing in } \delta$$

□

An illustration of the proof methodology is shown in figure A.1.4.

A.1.5 Optimal human capital investments

Figure 15 demonstrates that it is possible to sustain an equilibrium in the first stage, with some women choosing to invest in their careers, even if the second stage features non-monotonic matching. Figure 15 graphs a woman of skill t's payoff if she invests, $v(\lambda t,p)$ minus her payoff if she does not invest, $v(t,P)$, with P, the non-investment fecundity, set equal to 1, S, the max female skill, set equal to one, and Y, the max male income, set equal to two. In all these graphs, I add a small fixed cost of female education, as this generally insures there is a non-zero solution when λ is at its maximum value.

When the graph of $v(\lambda t,p)-v(t,P)$ is above zero, it means that the first stage will not be in equilibrium, because women just below t will want to also invest, to gain the greater utility. If the graph is below zero, women will regret investing. Therefore, the point at which the graph crosses zero, and thus $v(\lambda t,p)=v(t,P)$ represents the t^* that sustains an equilibrium in the first stage. If this crossing is between 0 and 1, the range of s (since $S=1$ in this section), there exists an interior equilibrium. If $t^*<0$, all women should invest, and if $t^*>1$, no women should.

The top left panel shows a λ—return on investment—of 1.5, with a fixed cost of education of 0.2. Under this relatively low return to education, the first stage equilibrium can be sustained with a probability of conceiving post-investment of 0.9 or 0.5, but not with 0.1. If the probability of conceiving post investment is 0.1, no women should invest. With a return to investment of 2, however, whom in the top right panel, the first stage equilibrium has an interior solution at all three levels of p. Note that for a fixed c and λ, t^* is decreasing in p, meaning that the higher the probability of conceiving post investment, the more women invest. Note also that for the same p and c, t^* will be lower for higher returns on investment, λ.

The bottom two panels confirm that these first-stage equilibria are possible with a λ that sustains the second-stage non-monotonic matching, by replacing λ with the maximum λ for which the equilibrium takes on the three-segment form, $\lambda = \frac{1}{p-1} + \frac{2t}{t+1}\frac{1}{p} + \frac{2c}{1+t}$ (where the last term results from the addition of the fixed cost, c, and the equation is simplified somewhat by the assumptions that $Y = 2$, $S = 1$, and $P = 1$).

This changes the shape of the curve, since the maximum λ depends on t and p, but shows that for all three levels of p, it is possible to have a first-stage equilibrium while within the boundaries of the λ required for a non-monotonic second-stage equilibrium. The left shows this image with the same fixed cost of education, $c = 0.2$, while the right side doubles this fixed cost, demonstrating that it simply shifts the equilibrium t^* outward for each λ and p.

A.2 Census Data

Figure 16 shows that the tradeoff between age at marriage and spousal income is especially high for highly educated women. These women realize the greatest gain in spousal income by waiting until their late twenties or early thirties to marry, due to either selection or marriage market returns to human capital accumulation, but also show the biggest drop-offs in spousal income for marriages after 30. This indicates that reproductive capital may be especially salient for those with the most to gain from making large career investments.

The lack of steepness in the drop-off for marriage market outcomes for women with less education could be simply because they never marry as wealthy of husbands to begin with, or could also be because of a stronger selection effect acting upon them. For college educated women, who have something to gain in terms of their own income by delaying marriage, delaying marriage is not indicative of not wishing to have children–these women report wanting children just as much in National Survey of Family Growth data. However, for women with only a high school education, whose income path is unlikely to be greatly changed by delaying marriage, waiting to marry is much more related to not wanting children, and choosing a partner who does not want children.

Figure 17 shows that conditional on income, marrying older is always worse for women, but not

Figure 15: Equilibrium t under different parameter values

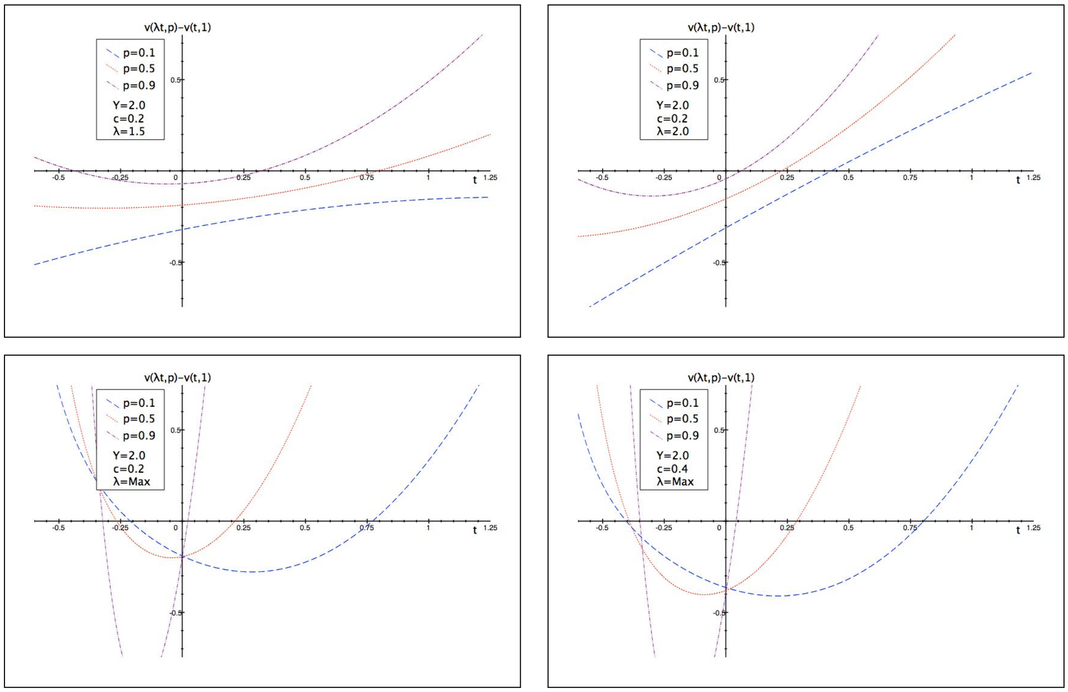
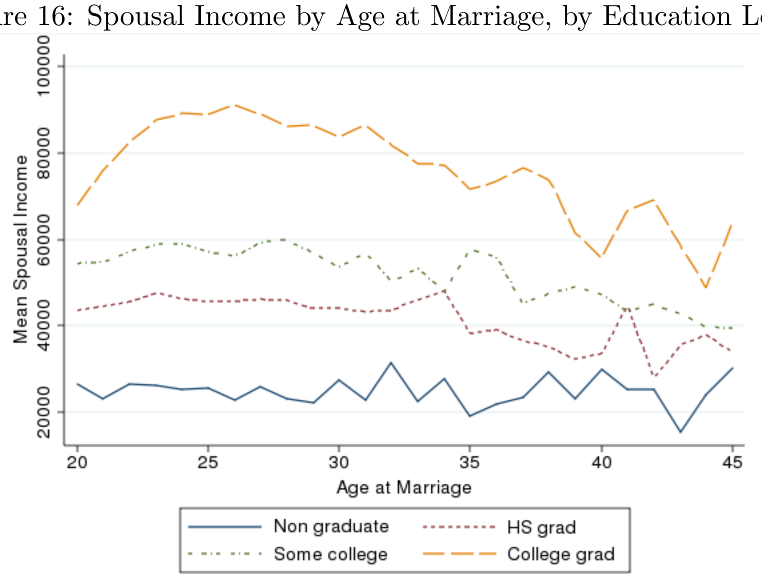
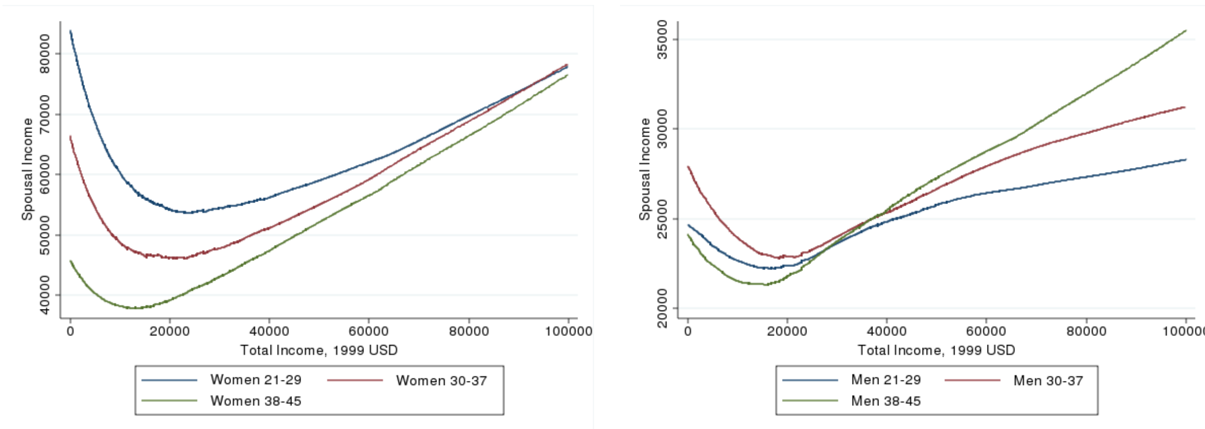


Figure 16: Spousal Income by Age at Marriage, by Education Level



for men.

Figure 17: Lowess-Smoothed Spousal Income for Women and Men who Marry at a Given Age, by Income



Figures 18 and 19 show that marriage outcomes for the 1920–1930 and 1940–1950 birth cohorts also exhibit the non-monotonicity shown in the 1930–1940 birth cohort. In the later cohort, the penalty has abated somewhat, with highly educated women only pairing with men who are no richer than college-educated women's mates, rather than statistically significantly poorer men.

Figure 20 shows that the wage premium for highly educated women has indeed risen since the 1940 birth cohort. This demonstrates that the rising wage premium could be responsible for a change of equilibrium. (Note, the falling premium for the earlier cohorts is likely due to more women making investments, thus changing the pool of each education group).

Figure 21 shows the rapid transition in desired family size during the 1960s and 1970s, which, if treated as exogenous to the model, could spur a shift between matching equilibria. This change was most likely brought on from the substitution from child quantity to child quality as overall wealth increases, and the rise of women in the workforce, increasing the opportunity cost of childbearing.

Figure 22 repeats Figure 11, using currently married rather than ever married as an outcome, and thus combining marriage and divorce rates.

Figure 23 repeats Figure 12, using ever divorced rather than currently divorced as an outcome, but necessarily omitting 1990 and 2000, where this data is not available.

Both Figures 22 and 23 demonstrate the same trend of increasing marriage rates and decreasing divorce rates for highly educated women, compared to college educated women.

Figure 18: Non-monotonicity in spousal income by wife's education level, 41-50 year old women in 1970 Census

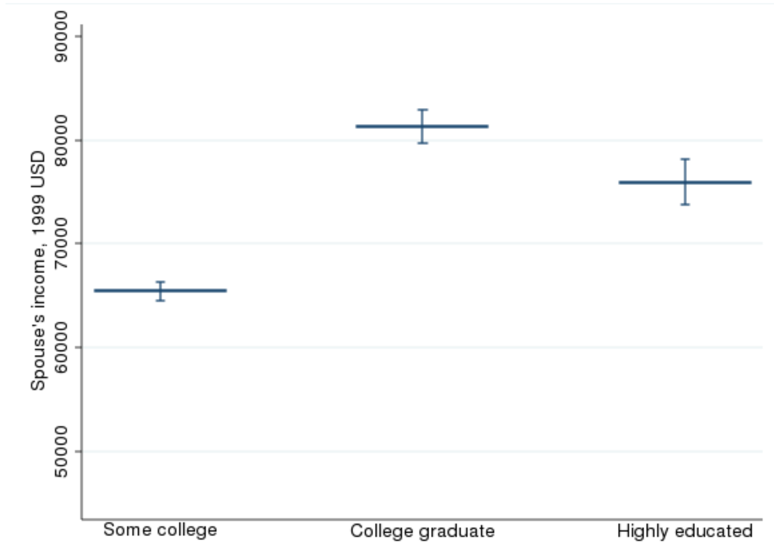


Figure 19: Non-monotonicity in spousal income by wife's education level, 41-50 year old women in 1980 Census

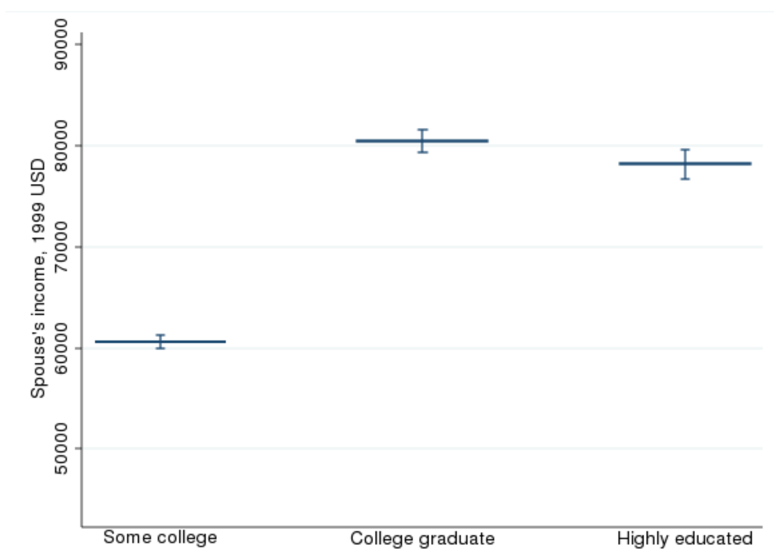


Figure 20: Wage premium over "some college"

Figure 21: Desired family size transition

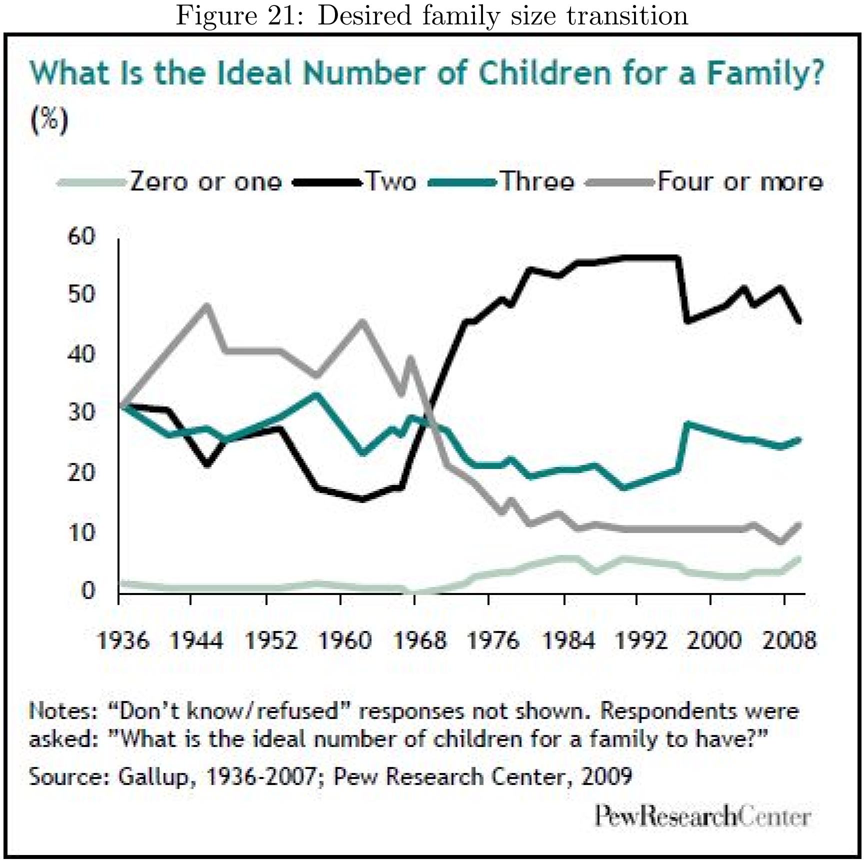


Figure 22: Currently married rates by education level, white women 41-50

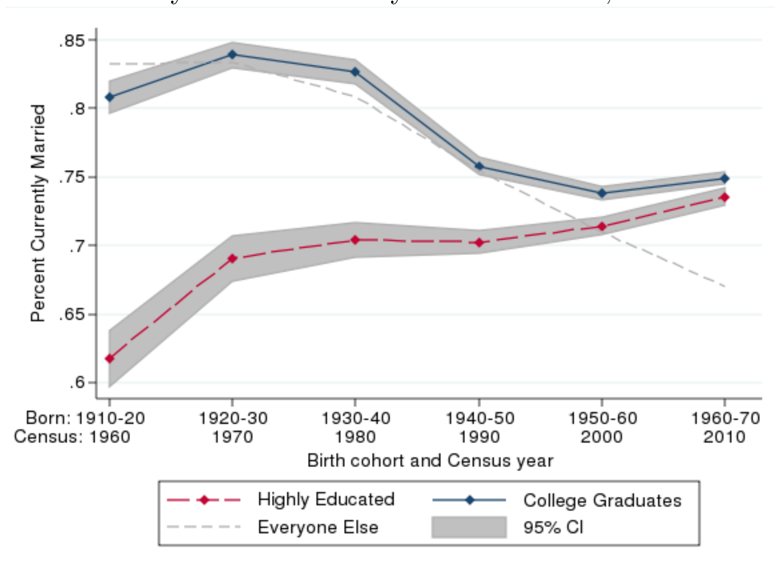
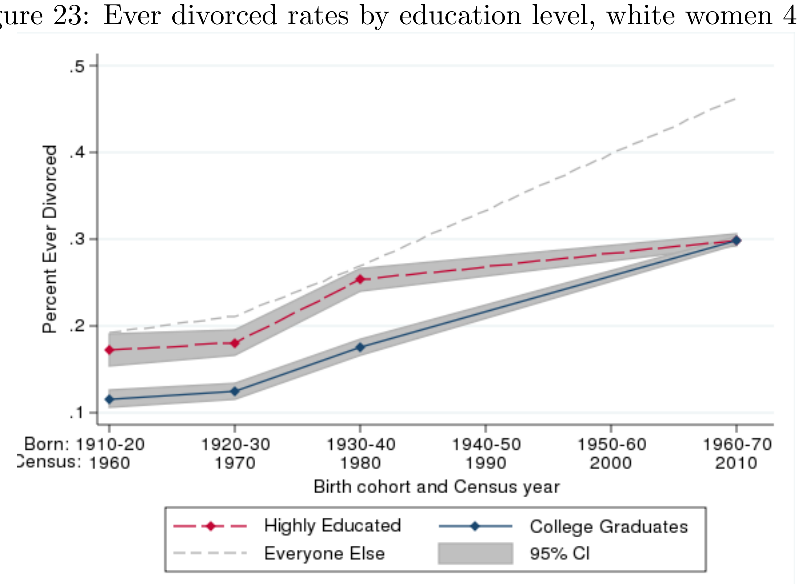


Figure 23: Ever divorced rates by education level, white women 41-50



A.3 Experiment

A.3.1 Test for plausibility of surplus function properties

The theoretical model derives predictions from two crucial assumptions. First, the surplus function is supermodular in the two spouses' incomes. Second, the surplus function exhibits a marginal rate of substitution between income and fertility that declines with income. This section uses the experimental data to test the plausibility of these assumptions. Although I cannot test the effect on the surplus function as a whole, which involves the men's and women's utilities added together, I can derive an understanding of the shape of the surplus function from individual preferences.

Table 10 tests for the second assumption, decreasing marginal valuation of income relative to fertility as income increases. The relationship between men's ratings of profiles and women's ages shown in the profile is indeed heterogeneous across income groups. This justifies the non-index approach to solving the matching model, since not all men value partner characteristics alike. However, rather than merely increasing in income, the age penalty appears to be U-shaped, with the poorest men having the greatest preference for young partners, middle income men having the lowest preferences, and the highest income men having higher preferences than the middle-income. This may be due to cultural norms acting on the lowest income men, while the model's mechanism of decreasing marginal valuation of income relative to fertility (due, in part, to the growing importance of investments in children in the overall surplus produced by marriage) may be causing the heightened valuation of age among the higher-income men. The increasing side of the "U," though, is the one most likely to impact individuals considering post-bachelors educational investments, and thus the relevant section for the model presented here. Additionally, because in both the three-segment and the positive assortative equilibrium the very poorest men *do* match with fertile women in the model, these equilibria would be robust to the very poorest men, in addition to the richest men, having heightened sensitivity to age. The negative assortative matching equilibrium may be ruled out by these preferences, however (in addition to being unlikely to appear due to typically assortative matching on social class).

For the first property, super-modularity in incomes, I look at the effect of the interaction between own income and profile income on overall rating. Table 11 shows that taste for partner income is indeed an increasing function of own income. In columns 1 and 2, the rater's own income interacted

Table 10: Income heterogeneity

Dep. variable: Profile rating	(1) **Age interaction**	(2) **Income and age**	(3) **Control for knowledge**
Age	-0.001	-0.001	-0.026*
	(0.012)	(0.012)	(0.014)
Income ($0,000s)	0.032***	0.034**	0.032**
	(0.007)	(0.014)	(0.014)
High income × age	-0.038**	-0.038**	-0.037**
	(0.016)	(0.016)	(0.016)
Low income × age	-0.070***	-0.070***	-0.063***
	(0.016)	(0.016)	(0.016)
High income × inc		0.022	0.025
		(0.017)	(0.018)
Low income × inc		-0.029*	-0.025
		(0.017)	(0.018)
No knowledge × inc			0.567***
			(0.126)
Observations	8,080	8,080	7,800
R-squared	0.491	0.492	0.490

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

with the profile's income has a positive and significant coefficient for regressions of each male and female ratings on profile characteristics, providing evidence for the supermodularity assumption. This table is discussed in more detail in the next section.

A.3.2 Alternative hypotheses: heterogeneous male or female tastes for income

I now examine evidence of possible alternative hypotheses that explain negative assortative matching at the top of the income distribution. The first alternative hypothesis that I test for is that *women* who are very high-earning may exhibit a less strong preference for income than lower-earning women, and thus the observed non-assortative matching could really be driven by women's tastes. The question, essentially, is whether women who are very high-earning have a lower marginal utility of additional income. Table 11 interacts the rater's income with the profile's income for both men rating women (column 1) and women rating men (column 2)—the resulting coefficients are positive and significant, for both male and female raters. As mentioned, this indicates that tastes over income appear to take the supermodular form assumed by the model—those with more income value additional partner income more. Columns 4 and 5 show that "high-income" raters, both

Table 11: Preferences over partner income, men and women

Panel A: Initial sample

Dep. variable: Profile Rating	(1) Male raters	(2) Female raters	(3) Male raters	(4) Female raters
Age	-0.043***	0.130***	-0.042***	0.130***
	(0.016)	(0.015)	(0.016)	(0.015)
Income ($0,000s)	0.011	0.034	0.012	0.085***
	(0.004)	(0.035)	(0.025)	(0.020)
Inc × rater inc	.008*	0.016***		
	(0.004)	(0.005)		
Inc × rater high inc			0.099***	0.128***
			(0.032)	(0.034)
Observations	1,360	1,760	1,360	1,760
R-squared	0.479	0.399	0.481	0.400

Panel B: Qualtrics sample

Dep. variable Profile Rating	(1) Men	(2) Women	(3) Men	(4) Women
Age	-0.043***	0.028***	-0.043***	0.028***
	(0.006)	(0.010)	(0.006)	(0.010)
Income ($0,000s)	-0.008	0.001	0.016*	0.024**
	(0.014)	(0.020)	(0.008)	(0.011)
Inc × rater inc	0.007***	0.008**		
	(0.002)	(0.004)		
Inc × rater high inc			0.040***	0.083***
			(0.013)	(0.029)
Observations	8,080	4,040	8,080	4,040
R-squared	0.491	0.464	0.491	0.464

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

male and female, have a greater taste for additional income, by interacting a dummy for having annual income over $65,000 with the income in the profile. Thus, I find no evidence of a decreasing marginal utility of income for women.

It is also possible that men dislike income itself in potential mates, perhaps due to gender norms, which could lead to the non-assortative matching at the top without reproductive capital. Men may not dislike all income equally, but may dislike it when women earn more than they do (e.g., Bertrand, Pan, and Kamenica, 2013), or may dislike *very* high-earning women. Table 12, column 1, regresses men's ratings on a dummy for whether the profile's listed income is higher than the rater's own income. The coefficient on "Profile earns more" is positive. The second column interacts the profile earning more with income, to see if the slope of additional income turns negative, or is much smaller, for marginal dollars after the rater's own income. The coefficient is negative, but non-significant, and it is much smaller than the main effect. Thus, marginal dollars of income still contribute positively to rating. The last column examines whether very high-income women are viewed less positively. Using a dummy for each income level, with the lowest income level, $20-34,999, as a baseline, we see that the coefficients on income level rise monotonically: the highest income level has a higher coefficient than all income levels before it.

A.3.3 Non-linearity in preferences over age

Table 13 checks for non-linearity in men's preferences over their partners' ages. If the preference for younger women displayed in the experiment is really a preference for fertility, then all years should not have equal weight in this calculation. Aging that takes place closer to the time when a woman may begin to have difficulty conceiving should be viewed more negatively than aging that is far before or far after this "infertility threshold." The age range that was presented to participants, from 30 to 40 years old, was too narrow to detect any non-linearity in the response to age. However, this non-linearity should most naturally occur in relation to the *perceived* infertility threshold of each respondent. Thus, by creating a new variable of profile age minus each respondent's individual belief regarding the infertility age, I effectively recover an expanded range of ages: from 20 years before infertility to 4 years after, restricting to cells with more than 100 data points. For example, if someone says that it becomes biologically difficult for a woman to conceive at age 36, and the profile age shown is 40, that data point becomes four years past infertility. If the respondent believes the

Table 12: Male preferences over partner income

Panel A: Initial sample

Dep. variable:	(1)	(2)	(3)
Profile rating	Binary	Interaction	By income level
Age	-0.042***	-0.043***	-0.043***
	(0.016)	(0.016)	(0.016)
Income ($0,000s)	0.062***	0.087***	
	(0.022)	(0.025)	
Profile earns more	0.029		
	(0.169)		
Earns more × inc		-0.021	
		(0.018)	
$35-49,999			0.283
$50-64,999			0.267
$65-79,999			0.486**
$80-94,999			0.515***
$95-109,999			0.590***
$110-124,999			0.631***
Observations	1,360	1,360	1,360
R-squared	0.477	0.478	0.478

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Panel B: Qualtrics sample

Dep. variable:	(1)	(2)	(3)
Profile rating	Binary	Interaction	By income level
Age	-0.043***	-0.043***	-0.043***
	(0.006)	(0.006)	(0.006)
Income ($0,000s)	0.027***	0.039***	
	(0.009)	(0.013)	
Profile earns more	0.053		
	(0.068)		
Earns more × inc		-0.006	
		(0.009)	
$35-49,999			0.134*
$50-64,999			0.151**
$65-79,999			0.205***
$80-94,999			0.213***
$95-109,999			0.264***
$110-124,999			0.343***
Observations	8,080	8,080	8,080
R-squared	0.490	0.490	0.490

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

age is 50, and the profile age shown is 40, that would be ten years prior to infertility, or -10.

For the analysis in table 13, errors are clustered at the profile level, because the "treatment" will be correlated with the raters' underlying characteristics, since only individuals who list very high infertility ages can have very negative values for "years past infertility," and only those who list very low infertility ages can have the upper range of "years past infertility" values. This also means that these results should be taken as suggestive only, as individual factors that may bias the response to age may be connected to those factors that cause one to list a higher or lower age at infertility. As in the other analysis that relies on heterogeneity across male respondents, these results are most reliably interpreted in Panel B, with the larger Qualtrics sample.

Column 1 substitutes the constructed years past the individual rater's "infertility cutoff" variable for profile age, showing a coefficient with similar magnitude and significance to the age analysis. Column 2 shows that when a squared term is added, this term is also negative and significant, indicating that distaste for additional years intensifies as age approaches and crosses the perceived infertility cutoff. Finally, column 3 demonstrates that the negative relationship between age and rating follows a backwards "s-curve": shallow, then steep, then shallow. The coefficient grows stronger as age approaches the respondent's perceived cutoff, with a negative and significant slope interaction for being between 6 and 10 years from the cutoff, and a stronger negative and significant effect for additional years within 5 years of the cutoff. Then, once the cutoff has been passed, the coefficient on additional years reverts back to its baseline level (with the interaction being statistically zero), the same as additional years more than 10 years from the cutoff. In the initial sample, these effects are not significant, but follow the same pattern.

Table 13: Non-linearity in aging using rater-specific fertility cutoffs

Panel A: Initial sample

Dep. variable: Profile rating	(1) Ind cutoff	(2) Cutoff^2	(3) By phase
Years past "infertile"	-0.049**	-0.090**	-0.049**
	(0.021)	(0.039)	(0.021)
Years past^2		-0.003	
		(0.002)	
Yrs past × 10–6 yrs pre			-0.027
			(0.021)
Yrs past × 5–1 yrs pre			-0.060
			(0.050)
Yrs past × 0–4 yrs post			0.125
			(0.146)
Income ($0,000s)	0.068***	0.068***	0.067***
	(0.023)	(0.023)	(0.023)
Observations	1,279	1,279	1,279
R-squared	0.474	0.476	0.476

Panel B: Qualtrics sample

Dep. variable: Profile rating	(1) Ind cutoff	(2) Cutoff^2	(3) By phase
Years past "infertile"	-0.038***	-0.083***	-0.031***
	(0.010)	(0.019)	(0.010)
Years past^2		-0.003***	
		(0.001)	
Yrs past × 10–6 yrs pre			-0.031***
			(0.009)
Yrs past × 5–1 yrs pre			-0.046**
			(0.019)
Yrs past × 0–4 yrs post			-0.001
			(0.048)
Income ($0,000s)	0.0320***	0.032***	0.032***
	(0.011)	(0.011)	(0.011)
Observations	6,833	6,833	6,833
R-squared	0.465	0.467	0.467

Robust standard errors in parentheses, clustered by respondent
*** p<0.01, ** p<0.05, * p<0.1