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Terms of endearment: An equilibrium model of sex and matching

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We develop a two-sided directed search model of relationship formation that can be used to disentangle male and female preferences over partner characteristics and over relationship terms from only a cross section of observed matches. Individuals direct their search for a partner on the basis of (i) the terms of the relationship, (ii) the partners' characteristics, and (iii) the endogenously determined probability of matching. Using data from the National Longitudinal Study of Adolescent Health, we estimate an equilibrium matching model of high school relationships. Variation in gender ratios is used to uncover male and female preferences. Estimates from the structural model match subjective responses on whether sex would occur in one's ideal relationship. The estimates show that some women would ideally not have sex, but do so out of matching concerns; the reverse is true for men. Counterfactual simulations show that the matching environment black women face is the primary driver of the large differences in sexual activity among white and black women.

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1. Introduction

Next to drinking alcohol, sex is the most common risky behavior of teens.[1] While numerous studies try to measure the impact of policies or technological changes on the sexual behaviors of teens[2] and others try to measure the effect of sexual activities on educational and health outcomes,[3] to our knowledge there are no economic studies of a fundamental trade-off faced by teens: the trade-off between being in a romantic relationship at all and the inclusion of sex in a relationship. We model and estimate this trade-off within the confines of the best available data on teen relationships and sexual behaviors. We show that in equilibrium some women have sex out of matching concerns. Further, as the gender ratio shifts to favor men, this effect becomes more pronounced.

To uncover differences in gender-specific preferences, we specify a model of two-sided directed search. Utilities in a relationship depend on partner characteristics and on the terms of the relationship. Individuals on one side of the market target their search toward potential partners with particular characteristics and also target their search based on the terms of the relationship (sex or no sex in our case).[4] Given the supplies of individuals on each side of the market, the ex ante yield from targeting particular partner characteristics and terms depends on the associated probabilities of matching. The probabilities of matching are in turn endogenously determined by the choices of individuals on one's own side of the market (rivals) and by all individuals on the other side (prospects). Changes in the supply of men and women of different characteristics shift the equilibrium distribution of relationships.

The supply of men and women of different characteristics coupled with the directed search model are what allow us to uncover differences in male and female preferences for terms. In particular, we rely on the competitive behavior of men and women when searching for a match. The main idea is that when men outnumber women, we tend to observe relationships characterized by what women want and conversely if women outnumber men.[5] Men and women target their search not only on the multidimensional

[1] The Youth Risk Behavior Surveillance System (YRBS) of the Centers for Disease Control and Prevention tracks the major risk taking behaviors of a national representative sample of 9th–12th graders. Summary statistics for 2011 show that more teens have had sex (47%) than ever used marijuana (40%), other illicit drugs, tobacco (44%), or attempted suicide. Only the behavior of ever having a drink of alcohol (71%) outranked sex (http://www.cdc.gov/mmwr/pdf/ss/ss6104.pdf).

[2] Akerlof, Yellen, and Katz (1996) discuss how abortion changed sexual participation; Girma and Paton (2011) study emergency contraception availability and unprotected sex.

[3] See Sabia and Rees (2008, 2009).

[4] This formulation of characteristics and terms builds on work by Dagsvik (2000), who develops a theoretical matching model with terms where agents have preferences over terms and observed match characteristics, and the preference distribution can in principle be backed out from observed aggregate matching patterns. Willis (1999) also presents an equilibrium model where the terms are joint or single parenthood, showing that sex ratio changes can generate equilibria where women raise children as single mothers.

[5] This fundamental idea has a long pedigree in the literature on intra-household allocations. McElroy and Horney (1981) and McElroy (1990) pointed to the gender ratio in the remarriage market as one member of a class of shifters (extra-environmental parameters (EEPs)) for the bargaining powers of spouses and thereby intra-household allocations. Chiappori (1992) (and elsewhere) suggested using these same shifters to study intra-household welfare.

characteristics of the partner but also on the terms of the relationship.[6] For example, a man may choose to search for a woman of a specific race where the relationship would include sex. With the terms of the relationship specified up front, utility is nontransferable. The probability of successfully finding a match then depends on the number of searchers on each side of the market. Searchers face a trade-off between having a low probability of matching under their preferred relationship terms and a higher probability of matching under less-preferred terms. For a large class of constant elasticity of substitution matching functions, we show that as the gender ratio becomes more unfavorable, the individual becomes more likely to sacrifice relationship terms for a higher match probability.

The advantages of our modeling approach are threefold. First, by linking choices over partners with outcomes, in equilibrium we are able to weight the different gender ratios appropriately. Standard practice is to use only one sex ratio when looking at the relationships between gender ratios and outcomes. But the relevant gender ratios are determined by equilibrium forces. Second, by allowing preferences over both partner characteristics and what happens in the relationship, we are able to capture the trade-offs made across the two when the matching environment changes. For example, increasing the number of senior boys favors women. This may, however, still result in more sexual relationships because the female preference for older partners may be stronger than the preference for not having sex. Finally, by working in a nontransferable framework with partner selection, we are able to identify individual-specific preferences for outcomes, and not only joint gains from matching.[7] In the transferable case, if the occurrence of a particular outcome is affected by the gender ratio, it is unclear how utilities are affected by the gender ratio because individuals may be making transfers not observed by the researcher, particularly in the case when the outcomes of relevance are discrete and two-sided (e.g., sex).

We estimate the model using data from the Add Health data. These data contain information on the universe of students at particular U.S. high schools in 1995 as well as answers to detailed questions about relationships for a subset of the students. The model is estimated assuming that individuals are able to target their search toward opposite-sex partners of a particular grade and race as well as to specify whether or not sex will occur in the relationship.

Not surprisingly, estimates of the structural model show that men value sexual relationships relatively more than women. By simulating choices in the absence of matching concerns, we find that 31.6% of women and 61.8% of men would prefer to be in a sexual, as opposed to a nonsexual, relationship. These counterfactual choices bear a striking resemblance to subjective reports by students found in Add Health. There, 34.6% of women and 58.3% of men responded that sex would be a part of their ideal relation-

[6]Recent empirical work by Dupuy and Galichon (2014) shows sorting in the marriage market is not unidimensional and individuals trade-off heterogeneous characteristics differently.

[7]Both Hitsch, Hortacsu, and Ariely (2010) and Fisman, Iyengar, Kamenica, and Simonson (2006) use observed choice and choice sets of both men and women to back out preferences for partner characteristics. Fisman et al. (2006) observe choices in a speed-dating experiment and Hitsch, Hortacsu, and Ariely (2010) observe them in an online-dating context. Chiappori, Oreffice, and Quintana-Domeque (2012) recover separate preferences for males and females for partner characteristics but not for relationship terms.

ship. Hence, our structural model, while estimated on observed matches, is able to back out preferences for sex that are remarkably close to the self-reports, providing some credence to both the self-reported data and our structural estimates. These estimates imply that matching concerns lead some women to have sex, not because they prefer this, but because they are willing to trade off relationship terms for a higher probability of matching.

We use the estimates of the structural model to understand racial differences in sexual practices. Conditional on matching, the data reveal that black females are substantially more likely to have sex than their white counterparts. We simulate changing the market black females face so as to understand the sources of the racial gap. We do so in two steps: first, examining the impact of blacks facing the same grade-specific gender ratios as whites, and, second, the impact of facing the same distribution of sexually experienced teens in the school. While changing the gender ratios has a substantial impact on match probabilities, their effect on the probability of sex conditional on matching is small. The primary driver behind differences in sex behavior between white women and black women is the strong preferences for own-race matches coupled with black males being substantially more sexually experienced than white males.

The rest of this paper proceeds as follows. The next section lays out a two-sided model of targeted search and matching, relates the matching function to special cases found in the literature, establishes the existence of equilibrium, and shows how the gender ratio affects the probability of matching. Section 3 presents the Add Health data on high school relationships. Section 4 describes the maximum likelihood estimator. Section 5 presents the resulting estimates and shows how the structural model can back out preferences in the absence of competitive effects, demonstrating how the model matches self-reported preferences on a number of dimensions. We also show the robustness of our results to different assumptions regarding searching outside the school as well as choosing not to search. Section 6 gives the counterfactuals. Section 7 offers an exploration of what our results imply about female welfare beyond the teen sex setting. Replication files are available in a supplementary file on the journal website, http://qeconomics.org/supp/429/code_and_data.zip.

2. Model

We analyze the trade-offs among three sources of expected utility from searching for a partner: the type of partner (race, grade), the terms of the relationship (sex/no sex), and the probability of success (matching). Individuals know in advance their payoffs from different partner types and relationship terms, and they may target less-preferred combinations of types and terms so as to have higher probabilities of matching. At its core, our model embeds search and the attendant risk of not matching into a static model.

To disentangle male and female preferences, we propose a two-sided search model with nontransferable utility and consider only opposite-sex, one-to-one matching. We categorize each male as a type m, where $m \in \{1, 2, \dots, M\}$. Similarly, each woman is given a type w, where $w \in \{1, 2, \dots, W\}$. An individual's type can denote some collection of observed characteristics such as age, grade, race, or attractiveness. For males (females) there are then W (M) types of mates. Let im indicate the ith member of type m.

We index the possible terms of the relationship by $r \in \{1, \dots, R\}$.[8] We model search as being completely directed: men and women are able to target their search on both the characteristics of the partner as well as the terms of the relationship. Each man (woman) then makes a discrete choice to search in one of $M \times R$ ($W \times R$) markets, resulting in $M \times W \times R$ types of matches.

Search is then modeled as a one-shot game: there are no dynamics in the model. Individuals first decide in which market to search. Couples are matched with the probabilities of matching depending on the number of searchers on both sides of the market.

2.1 *Individuals*

An individual's expected utility for searching in a particular market depends on three factors:

1. The probability of matching in the market where the probability of an m-type man matching with a w-type woman with relationship terms r is P_m^{wr}.
2. A deterministic portion of utility conditional on matching given by μ_m^{wr} for an m-type man.
3. An individual-specific preference term ε_{im}^{wr}.[9]

Note that the only individual-specific part of expected utility is ε_{im}^{wr} and that it is known to the individual before making his/her search decision. Hence, there is no match-specific component beyond what occurs through the observed characteristics of the partner and the terms of the relationship. We treat ε_{im}^{wr} as private information implying search decisions are based on the distribution of the unobserved preferences of the other students in the school, not their realizations. Finally, note that the probability of matching is only affected by male and female type and relationship terms: all males of type m searching in the $\{w, r\}$ market have the same probability of matching.

We normalize the utility of not matching to zero. Expected utility from searching in a particular market is then the probability of matching in the market times the utility conditional on matching. We specify the functional form of the utility such that expected utility for an m-type man searching for a w-type woman on relationship terms r is

$$E\left(U_{im}^{wr}\right) = P_m^{wr} \cdot e^{\mu_m^{wr} + \varepsilon_{im}^{wr}}. \tag{1}$$

Taking logs yields

$$\ln\left(E\left(U_{im}^{wr}\right)\right) = \mu_m^{wr} + \ln\left(P_m^{wr}\right) + \varepsilon_{im}^{wr}. \tag{2}$$

Individual i of type m then chooses to search for a woman of type w under relationship terms r, $d_{im} = \{w, r\}$, when

$$\{w, r\} = \arg\max_{w', r'} \mu_m^{w'r'} + \ln\left(P_m^{w'r'}\right) + \varepsilon_{im}^{w'r'}.$$

We assume that the ε_{im}^{wr}'s are independent and identically distributed (i.i.d.) type I extreme value errors and are unknown to the econometrician. In this case, we can esti-

[8] In our empirical application, $R = 2$, where the possible terms are sex and no sex.

[9] The corresponding terms for women are P_w^{mr}, μ_w^{mr}, and ε_{iw}^{mr}.

mate the error variance, σ, as a coefficient on the log probability term, capturing how the probability of matching influences utility. The probability of an m-type man searching for a w-type woman in an r-type relationship, ϕ_m^{wr}, then follows a multinomial logit form:

$$\Pr(w, r|m) = \phi_m^{wr} = \frac{\exp\left(\dfrac{\mu_m^{wr} + \ln(P_m^{wr})}{\sigma}\right)}{\sum_{w'}\sum_{r'}\exp\left(\dfrac{\mu_m^{w'r'} + \ln(P_m^{w'r'})}{\sigma}\right)}. \tag{3}$$

2.2 *Matching*

We now specify the matching process. The matching process is essentially a production function, taking as inputs the number of searching men and the number of searching women in each market and giving the number of matches in each market as an output. We parameterize the number of matches in market $\{m, w, r\}$, X_{mwr}, as depending on the number of m-type men and w-type women searching in the market. Let N_m and N_w indicate the number of m-type men and the number of w-type women overall. Recall that ϕ_m^{wr} and ϕ_w^{mr} give the probabilities, or shares, of m-type men and w-type women searching in market $\{m, w, r\}$. Thus $\phi_m^{wr} N_m$ is the number of men of type m searching for women of type w with relationship terms r. The number of matches in market $\{m, w, r\}$ is then given by[10]

$$\begin{aligned} X_{mwr} &= A^*\left[\frac{(\phi_m^{wr} N_m)^\rho}{2} + \frac{(\phi_w^{mr} N_w)^\rho}{2}\right]^{1/\rho} \\ &= A\left[(\phi_m^{wr} N_m)^\rho + (\phi_w^{mr} N_w)^\rho\right]^{1/\rho}, \end{aligned} \tag{4}$$

where ρ determines the elasticity of substitution (given by $(1/(1-\rho))$), and A measures search frictions. When $\rho \to 0$, the constant elasticity of substitution (CES) function becomes Cobb–Douglas, and as $\rho \to -\infty$, the CES function becomes Leontief. Note that $X_{mwr} = X_{wmr}$ for all m, w, and r.

Under the assumption that all m-type men searching in the same market have the same probabilities of matching, P_m^{wr} is given by

$$\begin{aligned} P_m^{wr} = \frac{X_{mwr}}{\phi_m^{wr} N_m} &= \frac{A\left[(\phi_m^{wr} N_m)^\rho + (\phi_w^{mr} N_w)^\rho\right]^{1/\rho}}{\phi_m^{wr} N_m} \\ &= A\left[1 + \left(\frac{\phi_w^{mr} N_w}{\phi_m^{wr} N_m}\right)^\rho\right]^{1/\rho}. \end{aligned} \tag{5}$$

[10] For ease of exposition we are assuming an interior solution such that the number of matches produced is less than both the number of men and the number of women in the $\{m, w, r\}$ market. In practice, we nest the CES matching function into a Leontief function to constrain the number of matches to be less than the number of searching men and women:

$$X_{mwr} = \min\left\{A\left[(\phi_m^{wr} N_m)^\rho + (\phi_w^{mr} N_w)^\rho\right]^{1/\rho}, \phi_m^{wr} N_m, \phi_w^{mr} N_w\right\}.$$

The log of this term then enters into the multinomial logit probabilities of searching in particular markets and it captures the influence of the gender ratio on search decisions.

2.3 *Equilibrium*

The ϕ's give the probabilities of searching in particular markets. But these ϕ's also affect the probabilities of matching, the P's. We rewrite equation (3) to make the dependence of P_m^{wr} on ϕ_m^{wr} and ϕ_w^{mr} explicit:

$$\phi_m^{wr} = \frac{\exp\left(\frac{\mu_m^{wr} + \ln[P_m^{wr}(\phi_m^{wr}, \phi_w^{mr})]}{\sigma}\right)}{\sum_{w'}\sum_{r'} \exp\left(\frac{\mu_w^{w'r'} + \ln[P_m^{w'r'}(\phi_m^{w'r'}, \phi_{w'}^{mr'})]}{\sigma}\right)}. \tag{6}$$

Since the market shares must sum to 1 for both men and women, equilibrium in our model is characterized by stacking the $(MR - 1)$ and $(WR - 1)$ shares and solving for the fixed point. Since ϕ is a continuous mapping on a compact, convex space, Brouwer's fixed point theorem guarantees that an equilibrium exists. As in macro models of the labor market, there is only one equilibrium where the search probabilities are positive in all markets. Diamond (1982) shows that a necessary condition for multiple equilibria (with positive search probabilities) in a similar model (with endogenous search on both sides of the labor market) is increasing returns to scale in the matching technology. There are other equilibria that result from coordination failures where certain markets are empty. We assume that the equilibrium being played is the one where search probabilities are positive in all markets. For example, if there is one 9th-grade white female, every male searching for her type believes he could match with her according to the (positive) match and search probabilities outlined above.

2.4 *Implications of changing the gender ratio*

Given our utility specification and matching process, we now turn to how changing the gender ratio leads to changes in the probabilities of choosing particular markets. To begin, consider two markets that include w-type women and m-type men but where the relationship terms in the two markets are given by r and r', respectively. Now, fix the search probabilities, the ϕ's, and increase the number of m-type men. We can then see which of the two types of relationships becomes relatively more attractive for men and women, respectively. We then show how the search probabilities must adjust in equilibrium.

Denoting G_w^m as the ratio N_m/N_w, Proposition 1 shows the relationship between the gender ratio and search behavior. The proof is given in Appendix A.

Proposition 1. *If* $\rho < 0$ *and* $\mu_w^{mr'} - \mu_w^{mr} > \mu_m^{wr'} - \mu_m^{wr}$, *then the following relationships hold*:

(a) *We have* $\frac{\phi_w^{mr}}{\phi_m^{wr}} < \frac{\phi_w^{mr'}}{\phi_m^{wr'}}$.

(b) *We have* $P_w^{mr} > P_w^{mr'}$ *and* $P_m^{wr} < P_m^{wr'}$.

(c) *Both* $\frac{\partial \phi_w^{mr'}/\phi_w^{mr}}{\partial G_w^m} > 0$ *and* $\frac{\partial \phi_m^{wr'}/\phi_m^{wr}}{\partial G_w^m} > 0$.

In Proposition 1 the average preference of a $\{m, w\}$ pair is such that the women in the pair have a stronger preference for terms r' over r than their male counterparts. The first two claims are intuitive. Claim (a) states that this relative preference by women for r' over r translates into search behavior: in equilibrium, the ratio of search probabilities for r' versus r must result in women searching relatively more in r' than men. These differential search probabilities then translate into different match probabilities. Since women are relatively more likely than men to search in r', female match probabilities must be lower in r' than in r, with the reverse holding for men, claim (b).

The key result for our empirical work is claim (c). As the gender ratio moves such that men become relatively more abundant, both men and women increase their relative search probabilities in the market where women have a relative preference, in this case r'. The result falls directly out of the elasticity of substitution. Namely, for elasticities of substitution less than 1 ($\rho < 0$), the lack of substitutability between men and women in the market implies that as G_w^m increases, larger changes in match probabilities for men (women) will occur where men are relatively more (less) abundant. The elasticity of the probability of matching with respect to G_w^m for men and women in the $\{m, w, r\}$ market conditional on ϕ are given by

$$\left.\frac{\partial \ln(P_w^{mr})}{\partial \ln(G_w^m)}\right|_\phi = \left[\left(\frac{\phi_w^{mr}}{\phi_m^{wr} G_w^m}\right)^\rho + 1\right]^{-1},$$

$$\left.\frac{\partial \ln(P_m^{wr})}{\partial \ln(G_w^m)}\right|_\phi = -\left[\left(\frac{\phi_m^{wr} G_w^m}{\phi_w^{mr}}\right)^\rho + 1\right]^{-1}.$$

With $\rho < 0$, as the ratio of male to female search probabilities (ϕ_m^{wr}/ϕ_w^{mr}) increases, the magnitude of the elasticity falls for females and rises for males. With fixed search probabilities, increasing the number of men relative to women makes the market where women have a relative preference more attractive for both sexes, resulting in shifts by both men and women to that market in equilibrium.

To illustrate this point, consider the Leontief case where ρ moves toward negative infinity $((1/(1-\rho)) \to 0)$. The matching function is given by

$$X_{mwr} = A \min\{\phi_m^{wr} N_m, \phi_w^{mr} N_w\}.$$

The number of matches is determined by whichever side of the market has fewer searchers. Hence, changes in the gender ratio have extreme effects on the group that is in the majority in a particular market, with no effect on the group in the minority.[11]

[11] On the other extreme is the Cobb–Douglas case where $\rho \to 0$, implying the elasticity of substitution, $(1/(1-\rho))$, is 1. Hence, if gender ratios do affect relationship terms, then this is evidence that the matching function is not Cobb–Douglas.

2.5 *Prior work on matching and our model*

Different models serve different purposes. By incorporating directed search into a matching model, we provide a static framework in which the preferences for terms are identified and the match-specific endogenous gender ratios reveal the rates at which individuals on both sides will substitute across (i) the terms of a relationship, (ii) the characteristics of one's partner, and (iii) the probability of matching at all. This approach expands the set of questions researchers can answer since the predominant search and matching models have difficulty investigating this three-way trade-off, for different reasons.

On the one hand, two-sided frictionless matching (assignment) models provide a flexible way to identify the gains to relationships for pairs across the partner characteristic distribution. However, these models are restrictive in how the changes in the sex ratio affect the distribution of matches; this is the unexpected symmetry result of Decker, Lieb, McCann, and Stephens (2013).[12] They also do not permit identification of preferences for match-specific terms such as sex.[13] Although individuals may trade off sex for other characteristics (in our model they trade off sex for partner characteristics and the probability of any match at all), sex is not a transfer because it is non-rival. One cannot "give up sex" so the other party can have sex without oneself having sex. This symmetry (with one-to-one matching the number of men and women in current sexual matches must be equal) means it is not possible to back out male-as-distinct-from-female preferences from one market. The same problem exists for other symmetric outcomes, like marriage or childbearing.[14] The key parameters we identify with data from multiple markets are (i) preferences for terms and (ii) matching technology parameters. In our model, uncertainty about matching serves to coordinate agents' decisions and, therefore, to clear the market, instead of transferring utility. In most transferable utility models, transfers are symmetric, but in our search model the "transfer" is essentially the negative utility associated with possibly not matching, which is always bigger for the group in the majority. Thus our Proposition 1 shows that the benefits from a change in the gender ratio are not equally distributed across sides of the market. This distinction prevents the transfers from canceling out and decentralizing the two-sided problem into two sets of one-sided problems (as in Galichon and Salanié (2014)). In our framework utility is lost due to uncertainty from search frictions rather than being delivered to the other side of the market.

[12]This is particularly restrictive in the context of relationship terms as the outside option in these models—being single—is the same for those who choose sex and those who do not. Consider the Choo and Siow (2006) setup where the number of m-type men equals the number of w-type women. Differentiating X_{mwr} with respect to the number of m-type men produces the same change in the number of matches as differentiating with respect to the number of w-type women, implying no shift in relationship terms.

[13]If transfers were observed, these models could identify pre-transfer utilities over characteristics. Choo and Siow (2006) introduced this framework and Galichon and Salanié (2014) studied identification of the systematic gains to marriage when relaxing assumptions about unobserved preferences and the observability of transfers.

[14]While in reality there may be both relationship terms and transfers, trying to identify both from the match distribution is beyond the scope of this paper.

On the other hand, while dynamic search models can both endogenize the sex ratio and help to explain the time profile of matching across characteristics, current computational considerations severely limit the number of individual-level characteristics included in empirical work.[15] For example Richards-Shubik (2014) models a very similar process to ours—the dynamics of sexual initiation—but it is precisely the complication of the dynamic process that leads him to aggregate across partner characteristics. Bronson and Mazzocco (2013) model the dynamics of changes in cohort size, which implicitly changes the gender ratio of young women to older men, leading to fewer marriages. But here too the types of partners are limited and differences in preferences across genders are not recovered. Hence our model complements existing search models by incorporating how the gender ratio forces trade-offs, but relaxing the computational burden to allow for many dimensions. In terms of market clearing, in dynamic models this arises through the optimal marriage delay of agents given expectations about future utility, whereas we coordinate decisions through the current probability of matching.

3. Data and descriptive characteristics

We now describe the data used to estimate the model. We use data from wave I of the National Longitudinal Survey of Adolescent Health.[16] The data include an in-school survey of almost 90,000 7th–12th-grade students at a randomly sampled set of 80 communities across the United States.[17] Attempts were made to have as many students as possible from each school fill out the survey during a school day. Questions consist mainly of individual data like age, race, and grade, with limited information on academics, extracurricular activities, and risky behavior. We use this sample to construct school level aggregates across observable characteristics such as grade and race by gender.

The Add Health data also include a random sample of students who were administered a more detailed in-home survey. The in-home sample includes detailed relationship histories and sexual behaviors. The relationship histories include both what happens within the relationships as well as characteristics of the partner. A natural problem in this survey design is the issue of what constitutes a relationship, particularly when men and women may define relationships differently. We define a relationship as consisting of both (i) holding hands and (ii) kissing. This definition results in the most symmetric distribution of responses within schools.[18]

[15] Bronson and Mazzocco (2013) and Beauchamp, Sanzenbacher, Seitz, and Skira (2014) both model the equilibrium distribution of singles (and therefore matching probabilities) across time. For other examples of dynamic search and matching models, see Brien, Lillard, and Stern (2006), Ge (2011), Gemici and Laufer (2011), Rasul (2006), Richards-Shubik (2014), and Wong (2003a, 2003b).

[16] The survey of adolescents in the United States was organized through the Carolina Population Center and data were collected in four waves: 1994–1995, 1995–1996, 2001–2002, and 2008.

[17] A school pair, consisting of a high school and a randomly selected feeder school (middle school or junior high school from the same district) were taken from each community.

[18] Applying this definition, 48.8% of ongoing in-school relationships in the in-home sample came from women and 51.2% from men. With perfect reporting, and assuming that the in-home sample is representative on gender, we would expect parity.

The Add Health data are nationally representative at the school level and so are drawn from all types of schools. We restrict attention to schools that enroll both men and women and focus on respondents who are in the 9th–12th grades.[19] We drop one all boys school, one vocational education school for high school dropouts, and six schools without meaningful numbers of 9th graders.[20] Since the focus here will be on a cross section of the matching distribution, we count only current relationships among partners who attend the same school.[21] Those matched with someone outside of the school are initially dropped. This is consistent with assuming the outside matching market is frictionless, which we relax in Section 5.3.[22]

Table 1 reports descriptive statistics for the sample. Roughly 30% of the sample are currently in a relationship and roughly half of these involve sex. Included in the descrip-

TABLE 1. Means by gender.

	Men	Women
Currently		
Matched (sex or relationship)	0.337	0.315
In a relationship	0.315	0.295
Having sex	0.185	0.159
Prior sex	0.321	0.237
Current sex$\vert$race		
White	0.189	0.166
Black	0.240	0.190
Hispanic	0.167	0.122
Other	0.074	0.099
Prior sex$\vert$race		
White	0.277	0.228
Black	0.527	0.314
Hispanic	0.365	0.189
Oher	0.191	0.136
N	3687	3418

Note: Sample includes only those searching in school, under the assumption that $P^{\text{out}}_{\text{match}} = 1$. Current is defined as ongoing at the time of the in-home survey. Relationship means holding hands and kissing; sex refers to sexual intercourse.

[19]The in-home sample is drawn from schools with different grades: 73% of schools have grades 9–12, 11% have grades 7–12, and 13% had other combinations of grades (e.g., K–12). Finally 1.4% are drawn from a junior and senior high school that are distinct schools.

[20]These schools on average had around 300 students in each of the grades 10–12, but on average 9 students in the 9th grade. The Add Health sampling design only probabilistically included the most relevant junior high or middle school for a high school; the relevant 9th grade observations for these six schools were not sampled, but rather a small "feeder" school. Schools for whom we observe fewer than 10 students in the detailed interviews are also dropped.

[21]A sample of ongoing relationships showed 55% of partners met in the same school; the next closest avenue of matching was mutual friends, accounting for only 24% of matches.

[22]From 14,840 students between grades 9 and 12, we drop schools discussed above (2622), schools with fewer than 10 reported students (146), unweighted data (996), missing data (106), and those matching outside the school (3771), giving 7141 valid observations for in-school searchers.

tive statistics is whether the individual has had sex prior to their current relationship.[23] Men report significantly higher rates of prior sex than women. Black men and women have had sex more than whites, but the gender gap in past sex is larger for blacks.

In theory, men and women should report roughly the same number of relationships but in practice this is not the case. Given that we observe double reporting in these data, that is, men are asked to report their matches within a school and so are women, we can see these differences. Men reported 688 matches where sex occurred and 561 matches where sex did not occur, while women reported 551 matches with sex and 532 matches without sex. Unfortunately we cannot link individuals to their partners within the sample, meaning incorporating both sets of reports would double count an unknown subset of matches. To deal with both double counting and misreporting we use information about matches reported by women. This also ensures that our estimated results on differences in male and female preferences for sex are not driven by differences in self-reporting.

3.1 *Direct measures of preferences*

Some direct information on gender differences in preferences for sex can be found from questions that were asked in the in-home sample. Individuals were asked about whether they would want a romantic relationship over the next year and what physical events would occur between the partners. Included in the questions were whether the ideal relationship would involve having sex. Table 2 shows elicited preferences over sex and

Table 2. Stated preferences by gender.

Prefer	Men	Women
Relationship	0.961	0.971
Sex	0.607	0.360
Sex, by race		
White	0.583	0.349
Black	0.738	0.404
Hispanic	0.635	0.381
Sex, by grade		
9th	0.487	0.254
10th	0.583	0.361
11th	0.672	0.397
12th	0.723	0.480
N	3687	3418

Note: Answers come from questions on whether the respondents' ideal relationship over the coming year would include sex or a relationship as defined above.

[23] This variable was created from reports of the full relationship history and takes on a value of 1 if the person has had sex in the past with someone besides his/her current partner. Arcidiacono, Khwaja, and Ouyang (2012) provide evidence that once adolescent females become sexually active, they generally remain so.

relationships overall as well as by grade and race. Comparing Table 1 to Table 2, more individuals prefer having relationships than do, suggesting significant search frictions.

While preferences for relationships are the same for both men and women (over 95% want a relationship as defined), preferences for sex are not. While 60% of men would prefer to have sex, the fraction of women who prefer to have sex is only 36%. Preferences for sex rise with age for both males and females. Even so, comparing sex preferences of women in a particular grade with the sex preferences of men in any other grade shows stronger male preferences for sex: even 9th-grade men have stronger preferences for sex than 12th-grade women. Note from Table 1 that half of current relationships entail sex, which is higher than the self-reported preferences for women averaged over any grade, even conditional on wanting a relationship. This suggests the possibility that women may be sacrificing what they want so as to form relationships.

To investigate this further, Table 3 shows the probability of having sex conditional on whether the respondent's ideal relationship includes sex. The means are presented separately for men and women, showing that women who want to have sex are significantly more likely to have sex than men who want to have sex. Further, women who *do not* want to have sex are also significantly more likely to have sex than men who do not want to have sex. The second row shows that these male/female differences hold conditional on being matched: it is not just that women who want sex sort into relationships at a higher rate; they also see their preferences implemented within matches more frequently than similar men. In contrast, women who do not want to have sex see their preferences implemented within matches less frequently than similar men. Finally, we also condition on having had sex in past. Here we see that women who have not previously had sex but want to are 12 percentage points more likely to have sex than similar

TABLE 3. Conditional means of sex participation.

Observed	Women	Men	Difference
$P(\text{sex}\mid\text{want sex}=1)$	0.340	0.287	0.053**
N	1172	2127	
$P(\text{sex}\mid\text{want sex}=1, \text{matched})$	0.738	0.682	0.057**
N	539	895	
$P(\text{sex}\mid\text{want sex}=0, \text{matched})$	0.272	0.201	0.071**
N	344	537	
With no prior sex			
$P(\text{sex}\mid\text{want sex}=1, \text{matched})$	0.579	0.458	0.121**
N	280	389	
$P(\text{sex}\mid\text{want sex}=0, \text{matched})$	0.175	0.122	0.053**
N	279	441	
With prior sex			
$P(\text{sex}\mid\text{want sex}=1, \text{matched})$	0.911	0.854	0.057**
N	259	506	
$P(\text{sex}\mid\text{want sex}=0, \text{matched})$	0.719	0.538	0.180**
N	65	96	

Note: The asterisks * and ** denote significance at the 10% and 5% levels, respectively. Matched is defined has having either a relationship or sex in-school. Sample includes only in-school matches.

men conditional on being matched, again illustrating that women have an easier time finding sexual partners while men have an easier time finding nonsexual partners.

3.2 *The distribution of matches*

Whether sacrifices over the terms of the relationship are made may in part be dictated by the characteristics of the partner. Individuals may be willing to take more undesirable relationship terms when the partner is more desirable. We now turn to characteristics of the partner, focusing in particular on grade and race. Table 4 shows the share of relationships for each possible male/female grade combination. The most common matches are among individuals in the same grade, making up over 40% of all matches. The six combinations of an older man with a younger woman also make up a large fraction of observations at over 40%, leaving less than 20% of matches for women with younger men. While matched women are evenly distributed across grades, older men are substantially more likely to be matched than younger men. Even though 9th-grade men outnumber 12th-grade men by almost three to two, there are 2.5 times more matched 12th-grade men than 9th-grade men.[24] These results point toward younger women and older men being more desirable and hence they may have more control over the terms of the relationship.

Table 5 shows the patterns of cross-racial matching. As can be seen from the diagonal elements of the table, the vast majority of matches—over 85%—are same-race matches. In the set of minorities, Hispanic students date outside their race/ethnicity most often, followed by those in the other category (who are predominantly Asian), and then blacks. Hispanic and black men see much higher probabilities of matching with other races than their female counterparts while the reverse is true for whites and those in the other category.[25]

Table 4. Cross-grade matching distribution.

	Male Grade					
Female Grade	9th	10th	11th	12th	Total	Fraction of Sample
9	0.085	0.066	0.064	0.035	0.249	0.301
10	0.031	0.099	0.086	0.085	0.302	0.279
11	0.021	0.041	0.092	0.087	0.241	0.234
12	0.005	0.018	0.054	0.130	0.208	0.186
Total	0.142	0.225	0.296	0.337	1.000	
Fraction of sample	0.276	0.280	0.246	0.198		1.000

Note: Distribution from 975 within-school matches with valid partner grade reported. Fraction of sample refers to sample of in-school searchers under the assumption that $P^{\text{out}}_{\text{match}} = 1$.

[24]The data presented here are from the searching sample (i.e., removing those who matched outside the school) where we assume the rates of matching outside the school are the same in the in-home sample as in the in-school sample.

[25]Other studies have used multiple sources to quantify which races and genders do and do not engage in interracial dating: Lee and Edmonston (2005) offer many descriptives using U.S. Census data to track

Table 5. Cross-race matching distribution.

	Male Race					
Female Race	White	Black	Hispanic	Other	Total	Fraction of Sample
White	0.577	0.010	0.046	0.008	0.641	0.577
Black	0.006	0.175	0.009	0.001	0.191	0.199
Hispanic	0.029	0.008	0.080	0.001	0.118	0.144
Other	0.011	0.007	0.009	0.022	0.050	0.080
Total	0.624	0.201	0.144	0.032	1.000	
Fraction of sample	0.611	0.162	0.146	0.081		1.000

Note: Distribution from 967 within-school matches with valid partner race reported. Fraction of sample refers to sample of in-school searchers under the assumption that $P^{\text{out}}_{\text{match}} = 1$.

3.3 *The gender ratio and its implications for relationship terms*

Given evidence that certain characteristics influence whether one's preferences will align with what happens in a relationship, the supply of these characteristics may also have an effect on the terms of the relationship. For example, when men are in short supply, women may need to sacrifice their preferences more so as to successfully match. We examine how gender ratios vary across schools in Table 6, paying particular attention to the gender ratios for whites and blacks by grade. Each cell in Table 6 gives the ratio of female to male students for each grade–race pairing.[26] Table 6 shows that there is a substantial amount of variation in the gender ratio, particularly among blacks.[27] Breaking out the gender ratio along different dimensions (race and grade–race groupings) spreads the initially condensed distribution.[28]

The bottom panel of Table 6 shows the probability of having sex conditional on matching at schools where the fraction of females is above the 75th percentile or below the 25th percentile. The first two rows show the cases when the gender ratio is measured using the whole school and then using only those of the same race. In both cases, a higher fraction of females is associated with more sex, though the differences are not large. The evidence in Section 3.2 showed that the most common matches are between those of the same race and grade so we next consider the percent female of the same grade–race pair as the partner. For a woman matching with a 12th-grade white male, this variable is the ratio of females to males among 12th-grade whites. Given the high likelihood of individuals matching in their own grade–race pair, this variable serves as a

interracial marriage over the last 40 years. The census shows a clear pattern with black men and Asian women marrying outside their race far more than black women and Asian men. Qian (1997) reports that white men marry most frequently whites, then Asians, Hispanics, and blacks.

[26]A minimum of five observations from the race or grade–race pair is required for a school to enter Table 6. Note that the gender ratio favors women here due to those matching outside the school being removed and women, particularly older women, being more likely to match outside the school.

[27]This dispersion is even more pronounced for Hispanic and other-race students in part due to smaller sample sizes.

[28]The populations have been scaled down by 1 minus the estimated conditional probability of matching outside the school for each age–race–gender–school group.

Table 6. Variation in gender ratios.

	Percentile		
Ratio of Females to Males	0.25	0.50	0.75
Total	0.794	0.898	1.002
White	0.772	0.885	0.994
9th	0.780	0.917	1.077
10th	0.769	0.914	1.095
11th	0.623	0.791	0.923
12th	0.613	0.813	0.957
Black	0.729	0.930	1.096
9th	0.481	0.891	1.178
10th	0.330	0.873	1.232
11th	0.352	0.797	1.145
12th	0.102	0.701	1.013
		Fraction Female	
		<25th	>75th
Overall fraction female			
$P(\text{sex}\mid\text{match})$		0.513	0.530
Same-race fraction female			
$P(\text{sex}\mid\text{match})$		0.491	0.552
Fraction female of partner's race–grade			
$P(\text{sex}\mid\text{match})$		0.496	0.564

Note: Based on a sample of 73 schools. Gender ratios are calculated using only those searching within the school. Aggregate gender ratio refers to the ratio of searching females to searching males.

crude measure of the outside options the partner faces. The final row of Table 6 shows that if the fraction of females in the partner's race–grade cell is higher, the probability of sex in the relationship is more likely: when women face more competition for partners, more sex results.

To further investigate the role of competition in determining relationship terms, Table 7 presents marginal effects from a probit of whether females in relationships had sex. We again use the ratio of females to males in the partner's grade–race cell as this gives us our best reduced form measure of the partner's outside options. The results from the reduced form are clear: increases in the outside options for male partners is associated with a higher probability of having sex. The second column indicates these results are strengthened when we control for school fixed effects. Increasing partner grade also affects the probability of having sex, even conditional on own grade and prior sex. Since older men appear to be more desirable for women, this suggests women are willing to give on their preferred relationship terms so as to match with a more preferred partner.

Note that the estimates in Table 7 do not account for the fact that the grade–race pair individuals matched with resulted from a choice to search in that market. The structural model outlined above specifically accounts for the endogeneity associated with the choice of partner characteristics.

Table 7. Reduced form probability of sex conditional on matching.

	$P(\text{sex}\vert\text{match})$	
	(i)	(ii)
F/M ratio in partners' grade–race	0.089**	0.107**
	(0.044)	(0.051)
Prior sex	0.422**	0.434**
	(0.023)	(0.107)
Grade	0.069**	0.063
	(0.014)	(0.044)
Partner grade	0.027**	0.022
	(0.014)	(0.025)
School characteristics	Yes	No
School fixed effects	No	Yes
N	893	893

Note: Coefficients are probit marginal effects from the probability of having sex conditional on matching. Regressions are run for females and include only in-school searchers. All specifications include grade and partner grade, prior sex, prior sex interacted with own and partner grade, and indicators for each own and partner race combination. School characteristics are percent nonwhite, and total males and females with no prior sex and with prior sex. The asterisks * and ** denote significance at the 10% and 5% levels, respectively.

4. Estimation

Having discussed the trends in the data and the modeling approach, we now turn to integrating the data and the model for estimation. Types of men and women are defined at the grade–race level as suggested by the clear differences in matching patterns across race and grade. We classify relationships as one of two types: those that entail sex and those that do not. An individual is defined as being in a relationship without sex if the person meets the standards described previously (holding hands, etc.). An individual is classified as having a relationship with sex if the individual is having sexual intercourse in his/her current match, regardless of his/her relationship status. With 2 types of relationships, 4 grades, and 4 races, there are then 32 markets.

The next two subsections put structure on the utility function and show how to form the likelihood function given the constraints posed by the data. However, there are three additional issues that arise from our data: (i) the unobserved fraction of each type who searched outside the school,[29] (ii) the unobserved distribution of past sex among men, and (iii) unreported partner characteristics. We discuss how we deal with each of these issues in Appendix B.

[29]From the in-home sample, we know who is matched outside of the school. We then project the share of individuals in the whole school who match in the outside market. See Appendix B for how this is done. We then scale down the number of within-school searchers by the number of students who are predicted to match outside the school. As we discuss in Section 5.3, this is consistent with either (i) individuals matching in the outside market in a first stage or (ii) the probability of matching in the outside market being 1.

4.1 *Utility*

Rather than having separate μ's (utilities) for every type of relationship, we put some structure on the utility function. Denote the grade associated with an m-type man as $G_m \in \{1, 2, 3, 4\}$. When a man searches for a w-type woman, the grade of the partner is PG_w. Similarly, $R_m \in \{1, 2, 3, 4\}$ gives the race of an m-type man with the corresponding race of the potential w-type partner given by PG_w. We specify the utility of a nonsexual relationship as a function of the partner's grade and race as well as whether the partner is in the same grade as the searching individual, $SG_{mw} = I(G_m = PG_w)$ where I is the indicator function, and the same race, $SR_{mw} = I(R_m = PR_w)$.

Denoting searching in the no-sex market by $r = 1$, we formulate the deterministic part of utility for men and women matching in the no-sex market as

$$\mu_{mw1} = \alpha_1 SG_{mw} + \alpha_2 PG_w + \alpha_3 SR_{mw} + \sum_{j=1}^{4} I(PR_w = j)\alpha_{4j}, \tag{7}$$

$$\mu_{wm1} = \alpha_1 SG_{mw} + \alpha_5 PG_m + \alpha_3 SR_{mw} + \sum_{j=1}^{4} I(PR_m = j)\alpha_{6j}, \tag{8}$$

where the intercept of a nonsexual relationship is normalized to 0. To economize on parameters, this specification sets the extra utility associated with being in the same grade or being of the same race to be the same for men and women. The effect of partner grade and race, however, is allowed to vary by gender. The specification allows certain race–gender combinations to be more desirable than other race–gender combinations.

The utility of sexual relationships takes the utility of nonsexual relationships and adds an intercept that differs depending on whether the individual has had sex in the past, PS_{iw}. Note that we are not specifying that partners have preferences for individuals who have had sex in the past but rather those who have had sex in the past have preferences for sex now. Hence, the types m and w do not include past sex, and it is therefore not targeted. We also include a grade profile that captures the transition process into sexual activity (e.g., social, biological, and other factors changing as adolescents age). Denoting searching in the sex market by $r = 2$, we specify the deterministic part of utility for men and women matching in the sex market as[30]

$$\mu_{mw2}(PS_{im}) = \mu_{mw1} + \alpha_7 + \alpha_8 PS_{im} + \alpha_{12} G_m, \tag{9}$$

$$\mu_{wm2}(PS_{iw}) = \mu_{wm1} + \alpha_{11} + \alpha_8 PS_{iw} + \alpha_{13} G_w. \tag{10}$$

4.2 *Forming the likelihood function*

We do not observe all matches but only those in the in-home sample. However, we do observe gender, grade, and race for the population of students at each school. As de-

[30]Although men an women may differ in their preferences for sex, the effect of past sex is constrained to be the same for men and women. Allowing coefficients for past sex to vary by gender generates a problem with identification since we must integrate out over the probability that each male has had sex in the past because it is unobserved from female reporting.

scribed in more detail in Appendix B, by inferring population moments of past sex from the in-home sample, we can construct the choice probabilities for the entire school from the in-home sample. We take the relationships as defined by the women in the Add Health. Since women report their partner characteristics, we only require a sample of women (matched and unmatched) along with the aggregate type distributions of men and women to estimate our model.

The parameters that need to be estimated include those of the utility function and the parameters of the matching function, ρ and A. Denote θ as the set $\{\alpha, \rho, A, \sigma\}$. Denote $\mathbf{N}^{kr}_{j,ps}$ as the equilibrium number of searching j types with past sex ps who are searching for k types on relationship terms r. Let $\mathbf{N}$ denote the vector of the number of each type searching in each market with elements given by $\mathbf{N}^{kr}_{j,ps}$. Hence, $\mathbf{N}$ contains 64 elements where each element refers to a gender, grade, race, and past-sex combination. The male search probabilities enter the female respondent likelihood through $\mathbf{N}$. Denote $y_{iw} = 1$ if the ith woman of type w was in a current relationship at the time of the survey and is 0 otherwise. The woman is then considered matched if $y_{iw} = 1$. The woman's search decision, d_{iw}, is observed only if the woman was matched. Hence, we need to integrate out over the search decision for those who are not matched. The log likelihood for the ith woman of type w is then given by

$$\begin{aligned} L_{iw}(\theta) = I(y_{iw}=1)\Bigg[\sum_m \sum_r I\big(d_{iw}=\{m,r\}\big)\big(\ln\big[\phi^{mr}_w(\theta,\mathbf{N},PS_{iw})\big] \\ + \ln\big[P^{mr}_w(\theta,\mathbf{N})\big]\big)\Bigg] \\ + I(y_{iw}=0)\ln\Bigg[\sum_m\sum_r \phi^{mr}_w(\theta,\mathbf{N},PS_{iw}) \times \big(1-P^{mr}_w(\theta,\mathbf{N})\big)\Bigg]. \end{aligned} \tag{11}$$

Note that the probability of matching is not affected by past sex except through the search probabilities. Note also that the ϕ terms are the equilibrium probabilities of searching in each market for each type, and are thus functions of $[P^{mr}_w \; P^{wr}_m]$, through the $\mathbf{N}$ vector.

The likelihood described so far was for a generic school. Denote the schools in the data by $s \in \{1, \dots, S\}$. Summing the log likelihoods over all the possible female types at each school s implies that the parameters can be estimated using

$$\hat{\theta} = \arg\max_\theta \left(\sum_s \sum_w \sum_{i=1}^{N^s_w} L^s_{iw}(\theta)\right),$$

where a fixed point in the search probabilities for men and women is solved at each iteration. That is, within each school and for each iteration of the likelihood function, we must first solve an $m \times w \times r \times 2$ fixed point in the search probabilities $[\phi^{mr}_w \; \phi^{wr}_m]$ at the type level, where the final dimensionality (two) refers to the states of past sex being 1 or 0.

5. Results

The estimates of the structural model are presented in Table 8. Key to disentangling male and female preferences given observed matches is the effect of the different gender ratios on the search decisions. These gender ratios manifest themselves through their effect on the probability of matching. The parameters of the matching function, ρ and A, are identified through variation in matches across schools with different gender ratios and the overall match rate.[31] The estimates of ρ are significant and negative, ruling out the Cobb–Douglas matching model and confirming that gender ratios do affect the likelihood of observing particular matches.

Focusing our attention on the first column, the middle panel of Table 8 shows how sex is valued above and beyond the relationship itself. Consistent with the elicited preferences in Table 2, males on average have stronger preferences for sex than females. Those who have had sex in the past also have a much stronger preference for sex in the present. As adolescents age their utility from sex increases and this is particularly true for women.

The lower panel shows how partner characteristics affect the value of a relationship. Here we see that women prefer to be matched with older men and that men have a slight preference for younger women. Individuals also prefer to be matched with those in the same grade and with those of the same race. The relative preferences for males and females of particular races match those in the prior literature. For example, black men are more preferred by members of other races than black women.

Our preferred model is presented in column (i). In subsequent columns we present alternative models. Column (ii) only allows for gender differences in preferences for sex (thus model (i) nests model (ii)). Column (iii) includes a set of partner race–grade, partner race–partner grade, and partner race–past-sex interactions in addition to the parameters in column (i) (thus model (iii) nests model (i)).[32] Although the utility estimates look different between (i) and (ii) this stems from the utility parameters being scaled by a different σ. Judging solely by likelihood ratio tests, model (i) outperforms model (ii) and model (iii) outperforms our preferred model (i). However, model (iii)'s poor performance in matching stated preferences for sex (discussed in the next section) suggests that the model is overparameterized. In column (iv), we allow the distributions of the unobserved utility draws to differ by whether individuals have had sex in the past. The mean of the distribution is already shifted by inclusion of the past-sex indicator, so model (iv) only adds one parameter to our baseline model: a separate variance for

[31] In a two-market model with only male and female preferences for sex, ρ and A, the four parameters are not identified from only one school. That is, because within a school we observe three moments: (i) the overall gender ratio, (ii) the ratio of men who have sex relative to men who do not have sex (which equals that same ratio for women without sampling error), and (iii) the number of men unmatched (only the number of unmatched men or unmatched women is independent since we are counting the gender ratio overall). Thus the search friction A is identified by including multiple schools. See Hsieh (2012) for recent work on identification in models with different male and female preferences within a single market.

[32] Model (iii) includes three partner races, two gender, and three other characteristics (linear grade, linear partner grade, and past sex), and so has 18 ($= 3 \times 3 \times 2$) more parameters than model (i).

Table 8. Structural model estimates.

Matching Parameters	(i)	(ii)	(iii)	(iv)
ρ	−0.312**	−0.738**	−0.042	−0.259*
	(0.090)	(0.003)	(0.106)	(0.127)
A	0.415**	0.424**	0.422**	0.408**
	(0.002)	(0.001)	(0.002)	(0.016)
σ^{-1}	0.168**	0.778**	0.176**	0.192**
	(0.003)	(0.018)	(0.002)	(0.024)
$\sigma^{-1}_{ps=1}$				0.186
				(0.025)
Sex utility				
Male × sex (α_7)	−3.788*	4.821*	−2.023	−4.275
	(1.978)	(1.058)	(1.463)	(2.962)
Female × sex (α_9)	−17.662**	−3.906**	−17.721**	−15.239**
	(1.187)	(0.869)	(1.290)	(1.735)
Past sex × sex (α_8)	15.276**		14.306**	13.637**
	(0.973)		(0.981)	(1.904)
Male grade × sex (α_{12})	1.506**		0.987**	1.566**
	(0.475)		(0.412)	(0.909)
Female grade × sex (α_{13})	3.738**		3.787**	3.228**
	(0.481)		(0.386)	(0.497)
Match utility				
Same grade (α_1)	4.957**	7.412**	4.782**	4.375**
	(0.395)	(0.616)	(0.444)	(0.544)
Partner grade × boy (α_2)	−0.668*	−0.160	−0.526	−0.490
	(0.338)	(0.409)	(0.586)	(0.284)
Partner grade × girl (α_5)	4.750**	6.744**	4.788**	4.335**
	(0.243)	(0.710)	(0.326)	(0.571)
Same race (α_3)	10.298**	15.538**	9.723**	9.084**
	(0.506)	(1.305)	(0.040)	(1.319)
Partner black × boy (α_{4b})	−0.824	−2.132	1.727	−0.891
	(1.426)	(1.352)	(2.284)	(0.966)
Partner black × girl (α_{6b})	4.602**	6.068**	9.346**	3.958**
	(0.960)	(0.618)	(2.527)	(1.128)
Partner hisp × boy (α_{4h})	−7.276**	−10.625**	−0.577	−6.790**
	(1.464)	(1.766)	(2.445)	(1.014)
Partner hisp × girl (α_{6h})	−3.770**	−5.341**	0.240	−3.704**
	(1.404)	(1.246)	(1.911)	(0.979)
Partner other × boy (α_{4o})	−10.768**	−17.163**	−6.498**	−9.981**
	(1.773)	(2.407)	(0.159)	(2.077)
Partner other × girl (α_{6o})	−7.837**	−12.191**	0.836	−7.261**
	(0.881)	(1.700)	(1.001)	(1.066)
$-\log(\ell)$	4541.72	4732.7	4522.3	4541.4
p-value test against (i)		0.000	0.001	0.420
Parameters	18	15	32	19

Note: Estimates are from a sample of in-school searchers comprising 3449 females in 1083 two-sided matches. Standard errors are given in parentheses. Model (i) includes the 18 parameters listed; model (ii) removes interactions from sex utility; model (iii) adds interactions of past sex, own grade, and partner grade, with each of three partner race groups, doing so separately for males and females, adding 18 ($= 3 \times 3 \times 2$) parameters; model (iv) takes model (i) and interacts the error variance with past sex. The asterisks * and ** denote significance at the 10% and 5% levels, respectively.

the errors of individuals with past sex equal to 1. Based on the log likelihoods we cannot reject that the variance is the same across the two groups, and so we proceed with model (i).

5.1 *Model fitness*

Between the general equilibrium effects and the nonlinear nature of the specification, the magnitudes of the utility coefficients are difficult to interpret. However, we can use the coefficient estimates to back out the fraction of men and women who prefer sex to no sex absent concerns about matching. Namely, we can turn off the effects of the probability of matching and see what choices would have been made in the absence of having to compete for partners. We can then compare these model estimated preferences to the stated preferences discussed in Table 2. As the stated preferences were never used in the estimation, this constitutes an out-of-estimation-sample comparison; an agreement of the estimated and stated preferences can provide compelling evidence for the credibility of the underlying parameter estimates. We also examine the within-sample fit of our baseline model (i) and the extended model (iii) from Table 8.

The first three data columns of Table 9 show that the baseline model does a good job of matching the elicited preferences for sex, which we report in two ways: conditional (C) on wanting a match and unconditional (U). The elicited preferences show 34–36% of women prefer sex compared to 31.6% of women predicted by the model, while for men the elicited preference for sex is between 58% and 60% compared to a model prediction of 61.8%. The model predictions and self-reports both show a higher preference for sex among blacks relative to whites. Each race–gender cell shows agreement between the subjective probabilities and the modeled-predicted probabilities with the exception of Hispanic females. Preferences for sex by grade match well for men but the grade profile is too steep for women. The fourth data column shows the problem with the extended model. Namely, it does not do as well at matching the self-reported preferences of males: overall, across races, and for younger males.

The final three columns of Table 9 compare the observed frequencies of sexual relationships with the equilibrium predicted probabilities (i.e., the probability of search times the probability of matching). Both the extended and baseline models provide a reasonable fit to the underlying data, especially for females, with very little difference in the within-sample predictions between the two models.

Finally, our model gives predictions about the evolution of sexual histories. Here we use our model to forecast the distribution of individuals by grade and race who will enter the subsequent grade with sexual experience.[33] We present these model forecasts in Table 10. The model does an excellent job forecasting the 1-year evolution in sexual experience for white men and white women. For Hispanic females and black males and

[33] The fraction who have had sex in each grade (10–12) is the sum of (i) the fraction who had sex in the prior grade plus (ii) the fraction who had not had sex times the probability of searching and matching. Note that our calculations miss those who had sex outside of the school and then chose to search in the school in the next period as well as those who had sex in an in-school match but chose to search outside of the school in the next period.

Table 9. Observed and predicted preferences for sex.

	Preferences for Sex				Probability of Sex		
	Stated						
	(C)	(U)	Baseline	Extended	Observed	Baseline	Extended
Male	0.607	0.583	0.618	0.638	0.139	0.132	0.132
Female	0.360	0.346	0.316	0.308	0.158	0.148	0.148
Male							
White	0.583	0.563	0.603	0.628	0.135	0.126	0.127
Black	0.738	0.703	0.705	0.783	0.215	0.208	0.206
Hispanic	0.635	0.625	0.631	0.609	0.120	0.118	0.115
Grade							
9th	0.487	0.463	0.518	0.562	0.057	0.046	0.045
10th	0.583	0.559	0.595	0.619	0.089	0.095	0.099
11th	0.672	0.650	0.677	0.684	0.166	0.171	0.172
12th	0.723	0.700	0.743	0.735	0.284	0.278	0.274
Female							
White	0.349	0.339	0.318	0.308	0.168	0.156	0.160
Black	0.404	0.379	0.354	0.323	0.188	0.173	0.183
Hispanic	0.381	0.370	0.299	0.306	0.120	0.120	0.108
Grade							
9th	0.254	0.242	0.153	0.145	0.089	0.094	0.092
10th	0.361	0.350	0.277	0.267	0.171	0.138	0.140
11th	0.397	0.380	0.419	0.410	0.187	0.185	0.186
12th	0.480	0.465	0.542	0.539	0.221	0.212	0.212

Note: The male observed probabilities are obtained by ignoring male reporting of sex and adding female reports to the number of men who did not report sex. Stated and observed preference means come from a sample of both men ($N = 3423$) and women ($N = 3449$). The Baseline and Extended columns set the probability of matching to 1, and report the average choice probability across individuals based only on preference parameters. The predicted probability of sex means are the product of search and matching probabilities at the equilibrium.

females, the predictions of the model suggest a much more rapid rise in the rates of sexual activity than what is actually seen in the data. A potential reason for the poor fit for blacks is differences in high school dropout rates. Namely, the evolution we predict assumes that the same students would be present a year from now. To the extent that those who drop out are more likely to engage in sex or, in the case of females, drop out because of a pregnancy, it is not surprising that our predictions regarding the fraction entering the next year having had sex is too high.

5.2 *Equilibrium match probabilities*

Table 11 presents the estimated equilibrium match probabilities for whites in same-race markets. The table is partitioned into 16 cells, one for each possible female grade–male grade match. The columns within each cell report the probabilities of matching for men (P_m^w) and women (P_w^m). The first column gives the probabilities that a 9th-grade male matches in his eight possible markets (sex or no-sex market with women in four grades).

Table 10. Model forecast of past sex.

	Females		Males	
	Predicted	Observed	Predicted	Observed
Whites				
Grade				
10	0.192	0.220	0.217	0.246
11	0.293	0.298	0.296	0.322
12	0.388	0.373	0.410	0.403
Blacks				
Grade				
10	0.249	0.328	0.456	0.474
11	0.370	0.392	0.566	0.551
12	0.481	0.410	0.675	0.591
Hispanics				
Grade				
10	0.161	0.170	0.277	0.302
11	0.268	0.205	0.365	0.430
12	0.352	0.222	0.476	0.467

Note: Predicted past-sex probabilities come from simulating the equilibrium model, adding those who initiated sex during the simulated year to the stock of those who already had sex in the past.

Table 11. Equilibrium probabilities of matching: whites.

	Searcher Grade and Gender							
	9		10		11		12	
Partner Grade and Terms	*m*	*w*	*m*	*w*	*m*	*w*	*m*	*w*
9								
Sex	0.07	1.00	0.13	0.95	0.22	0.72	0.33	0.51
No sex	0.23	0.69	0.38	0.45	0.63	0.26	0.95	0.14
10								
Sex	0.11	1.00	0.18	0.81	0.28	0.59	0.42	0.41
No sex	0.20	0.75	0.34	0.50	0.58	0.29	0.88	0.15
11								
Sex	0.12	1.00	0.19	0.79	0.29	0.57	0.44	0.39
No sex	0.15	0.90	0.26	0.62	0.46	0.37	0.73	0.21
12								
Sex	0.11	1.00	0.18	0.81	0.28	0.59	0.42	0.41
No sex	0.10	1.00	0.19	0.77	0.35	0.48	0.59	0.28

Note: Each cell gives the probability of matching in sex or no-sex markets based on an individual's grade and possible partner grade. The term P_m^w is the probability of matching for a man looking for a woman; P_w^m is the probability of matching for a woman looking for a man.

The four columns headed by P_w^m in the first row give the comparable eight probabilities for 9th-grade women.

The grade-matching patterns are driven by the equilibrium combination of utility parameters and the probability of matching. As expected, 9th-grade males—in both the sex and the no-sex markets—see the lowest match probabilities of any group. Indeed, females can always match with a 9th-grade male in the sex market. For females, the probability of matching declines with partner grade because of a female preference for older men. But the rate at which female match probabilities decline with partner grade is such that the declines are particularly large in the no-sex market. With older men in relatively scarce supply, women must be willing to search in the sex market for a reasonable chance of matching with these men.

5.3 *Robustness checks*

We now relax assumptions on who searches outside the school and whether all individuals search, showing that our estimated differences in preferences between males and females are robust to alternative assumptions. Previously we removed individuals matched with someone outside of the school. This assumption is consistent with either (a) individuals searching and matching in the outside market in a first stage or (b) the probability of matching being 1 in the outside market. To see (b), note that only those who matched in the outside market will have searched in the outside market. Denote o as the outside market. The probability of an m-type man searching in the $\{m, w, r\}$ market is

$$\Pr(w, r|m) = \frac{\exp\left(\dfrac{\mu_m^{wr} + \ln(P_m^{wr})}{\sigma}\right)}{\sum_{w'}\sum_{r'} \exp\left(\dfrac{\mu_m^{w'r'} + \ln(P_m^{w'r'})}{\sigma}\right) + \exp\left(\dfrac{\mu_m^{o}}{\sigma}\right)}. \tag{12}$$

Using the independence of irrelevant alternatives (IIA) property, note that this probability conditional on searching in the school is

$$\Pr(w, r|m, d \neq o) = \phi_m^{wr} = \frac{\exp\left(\dfrac{\mu_m^{wr} + \ln(P_m^{wr})}{\sigma}\right)}{\sum_{w'}\sum_{r'} \exp\left(\dfrac{\mu_m^{w'r'} + \ln(P_m^{w'r'})}{\sigma}\right)}, \tag{13}$$

which is the probability in equation (3) that we used to form our likelihoods, assuming everyone who did not match in the outside market searched within the school.

When the probability of matching in the outside market is not 1, the IIA property still holds, but we no longer have a good measure of the number of searchers in the outside market. We do observe the probability of an outside match occurring, which is the product of the probability of searching and matching outside the school,

$$P(\text{match out}|m, s) = P_{m,s}^{\text{out}} \times \phi_{m,s}^{\text{out}}, \tag{14}$$

where m denotes a male type and s denotes their school and analogous expressions hold for females. With one observation and two unknowns in each market, we explore the robustness of our results to different values of $P^{\text{out}}_{m,s}$, the probability of matching outside conditional on searching outside the school. We then reestimate the model under the different assumptions regarding the probabilities of matching outside the school and see how our estimated gender differences change.

In particular, using different values of $P^{\text{out}}_{m,s}$ and knowing the share of each type who matched outside of the school, we back out the implied outside-the-school search probabilities. In our robustness checks, we set $P^{\text{out}}_{m,s}$ to be the same regardless of the characteristics of the individual. For example, suppose the outside match probability was set at 0.8. If 10% of freshmen girls and 16% of senior girls matched in the outside market, the implied outside-the-school search rates would be 12.5% and 20%, respectively. We then shrink the number of within-school searchers by taking out the implied number of students who searched but did not match in the outside market.

More formally, denote N^o_m as the number of m-type men who matched in the outside market. The term N_m was defined as the number of searching men of type m in the school and was formed as the total number of m-type men minus N^o_m. With the probability of matching in the outside market given by P^o_m, instead of forming N_m by subtracting off N^o_m for the population, we subtract off N^o_m/P^o_m. Note that the utilities of searching in the outside market are allowed to vary conditional on school fixed effects and individual characteristics. The only restriction is that, conditional on searching in the outside market, the match rate is the same. We need this to characterize the number of individuals searching inside the school.

Another assumption made throughout is that all individuals engaged in search. Using data on the history of matching prior to wave I, we relax this assumption by assuming a given fraction of those individuals who never matched (never had sex and never had a relationship in the past or present) were uninterested in searching for an opposite-sex partner. Assuming some individuals decided in a first stage not to search, we again drop individuals randomly from the group who have never matched and reestimate the model. We do this both with and without the assumption that all unmatched individuals who searched did so in the school. We then reestimate the model in this new environment and again see how our estimated gender differences change.

Results for the estimated models under different match rate assumptions are presented in Table 12, with the first data column repeating the results of the original model. The top rows of Table 12 show the mean choice probability for choosing sex without equilibrium influences. As we move across the table, the composition of the sample changes as a greater share of individuals move toward searching in the outside market or are taken out of searching all together. We again use the subjectives as a check on the appropriate outside-market match rate. Lowering the probabilities of matching outside the school by themselves (data column 2) has little effect on our estimated shares of men and women who are interested in sex. Data columns 3–6, which remove a share of those who never matched from the search pool, however, perform worse by underpredicting interest in sex for both men and women.

Table 12. Varying first-stage assumptions.

	% Never Matched Removed					
	0		25		50	
	P^{out}_{match}		P^{out}_{match}		P^{out}_{match}	
	1	0.66	1	0.66	1	0.66
Mean ϕ_{sex}						
Male, no equilibrium	0.618	0.628	0.568	0.579	0.485	0.498
Female, no equilibrium	0.316	0.302	0.362	0.344	0.425	0.395
Mean stated preference						
Male	0.583	0.587	0.608	0.600	0.630	0.621
Female	0.346	0.352	0.370	0.368	0.387	0.384

Note: To decrease the probability of matching outside the school, we adjust the number of unmatched who searched as discussed in Section 5.3. We remove never matched individuals randomly from the individual sample of searchers, and shrink the aggregate number of searching men and women by multiplying them by the probability of ever matching. This probability is estimated from logit on ever matching at the type–school–gender level.

6. Counterfactuals

Having recovered the matching technology and preferences, the structural model permits us to perform counterfactual simulations. We aggregate our sample of 73 Add Health schools to create one large, representative school.[34] We perform an initial simulation that shows how changes in the aggregate gender ratio affect men and women differently by grade. Namely we increase the percent female by 10% in the aggregate school, from 0.473 to 0.521, and examine the resulting changes in the probabilities of being single and having sex, along with utility and market shares.

Results for white–white matches are presented in Table 13. All panels show percentage point changes in the probabilities, except the final panel, which shows expected utility. A common feature across panels is the differential effects by grade: the first panel shows the reductions in the probability of being single among men are higher for older males. Similarly older females see a bigger increase in the probability of being single than younger women.

The probabilities of sex track the probabilities of matching, but the probability of sex conditional on matching reveals compromises in preferred relationships so as to match at all. Market shares also reflect changes in utility, with younger females seeing larger reductions in the chances of matching with older males (whom they prefer based on our estimates). Market shares for matching with younger partners drop for males, reflecting substitution toward having sex, but overall the grade-specific patterns show very little substitution across partner grade. Finally, all the movements in terms and partner characteristics arising in the counterfactual equilibrium can be summarized by changes in expected utility. Females lose on average, as expected, but older women lose substantially more. The largest gains in utility accrue to 9th-grade boys, who also have the largest increase in the probability of sex conditional on matching.

[34]The constant returns-to-scale matching technology makes the number of individuals irrelevant.

Table 13. Counterfactual outcomes for whites.

	Females		Males	
	Baseline	CF Changes	Baseline	CF Changes
P(single)				
9th grade	69.82	2.56	86.21	−2.06
10th grade	66.51	2.94	77.75	−2.64
11th grade	62.45	3.45	66.27	−3.56
12th grade	62.26	3.36	51.62	−4.35
P(sex)				
9th grade	10.36	−0.56	4.24	0.84
10th grade	15.17	−1.15	8.90	1.22
11th grade	20.56	−1.76	16.40	2.00
12th grade	23.70	−2.04	27.28	2.93
P(sex|match)				
9th grade	34.33	1.17	30.72	1.32
10th grade	45.30	0.59	39.99	0.66
11th grade	54.76	0.38	48.60	0.73
12th grade	62.79	0.19	56.39	0.92
Market shares: older				
9th grade	71.54	−0.90	47.54	0.31
10th grade	49.89	−0.64	28.16	0.28
11th grade	26.97	−0.41	13.54	0.14
12th grade	–	–	–	–
Market shares: younger				
9th grade	–	–	–	–
10th grade	11.25	0.35	21.41	−0.10
11th grade	24.99	0.48	41.10	−0.28
12th grade	40.65	0.86	59.17	−0.33
E(utility)				
9th grade	0.92	−0.09	0.20	0.03
10th grade	1.17	−0.11	0.37	0.05
11th grade	1.55	−0.15	0.64	0.08
12th grade	1.83	−0.17	1.06	0.11

Note: This simulation increases the percentage female in the aggregate school by 10%. The CF change numbers are percentage point changes in the (baseline) probabilities, except for expected utility, which is reported as the change in utils from the baseline level.

6.1 *Black women and counterfactual environments*

Next we examine why it is that black women in relationships are roughly 10 percentage points more likely to have sex than white women. We focus on how much of this gap is driven by differences between the matching markets faced by blacks and whites. Black women face a different market than white women along at least two dimensions: (i) the same-race fraction of females is much higher for black women and this fraction rises faster with grade level and (ii) the probability of past sex for black males is far higher than for white males. These differences all push the competitive equilibrium toward one in which black women have more sex than their white counterparts.

Our simulated counterfactuals move the matching markets faced by blacks closer to those faced by whites in two counterfactual steps. First, we change the grade-specific gender ratios among blacks to match those of whites, keeping the distribution of other individual characteristics fixed. This is done by removing black women and adding black men while holding the total number of blacks constant. Second, we change the distribution of past sex among black men to match that of white men.

In Table 14 we present the aggregate school matching probabilities for black men (P_m^w) and black women (P_w^m), focusing on same-race matches. As seen in the first two rows in the upper left cell, a 9th-grade black female has a dramatically higher probability of matching in the sex market than her male classmate and her male classmate

Table 14. Counterfactual probabilities of matching: blacks in aggregate school.

Partner Grade, Terms, and Counterfactual	Searcher Grade and Gender							
	9		10		11		12	
	m	*w*	*m*	*w*	*m*	*w*	*m*	*w*
9								
Sex baseline	0.11	1.00	0.19	0.78	0.31	0.55	0.47	0.36
No-sex baseline	0.33	0.51	0.57	0.29	0.90	0.15	1.00	0.05
Sex CF: only GR	0.10	1.00	0.17	0.83	0.28	0.59	0.43	0.40
No-sex CF: only GR	0.31	0.54	0.52	0.32	0.85	0.17	1.00	0.06
Sex CF: GR-MPS	0.12	1.00	0.19	0.79	0.30	0.56	0.46	0.38
No-sex CF: GR-MPS	0.27	0.61	0.45	0.38	0.74	0.20	1.00	0.09
10								
Sex baseline	0.15	0.90	0.24	0.66	0.38	0.45	0.57	0.29
No-sex baseline	0.29	0.58	0.50	0.34	0.82	0.17	1.00	0.07
Sex CF: only GR	0.13	0.95	0.21	0.72	0.34	0.50	0.52	0.33
No-sex CF: only GR	0.26	0.62	0.45	0.38	0.76	0.20	1.00	0.08
Sex CF: GR-MPS	0.15	0.89	0.23	0.68	0.36	0.47	0.54	0.31
No-sex CF: GR-MPS	0.23	0.69	0.39	0.44	0.66	0.24	0.99	0.12
11								
Sex baseline	0.15	0.90	0.24	0.66	0.38	0.45	0.57	0.29
No-sex baseline	0.21	0.74	0.38	0.45	0.65	0.25	1.00	0.12
Sex CF: only GR	0.13	0.96	0.21	0.73	0.34	0.50	0.52	0.33
No-sex CF: only GR	0.18	0.79	0.34	0.50	0.59	0.28	0.93	0.14
Sex CF: GR-MPS	0.15	0.90	0.23	0.68	0.36	0.47	0.54	0.31
No-sex CF: GR-MPS	0.16	0.86	0.29	0.58	0.51	0.33	0.81	0.18
12								
Sex baseline	0.14	0.95	0.22	0.71	0.35	0.49	0.53	0.32
No-sex baseline	0.14	0.92	0.28	0.59	0.50	0.34	0.81	0.18
Sex CF: only GR	0.12	1.00	0.19	0.77	0.31	0.54	0.48	0.36
No-sex CF: only GR	0.13	0.98	0.25	0.65	0.45	0.38	0.75	0.20
Sex CF: GR-MPS	0.14	0.95	0.21	0.72	0.33	0.51	0.50	0.34
No-sex CF: GR-MPS	0.10	1.00	0.21	0.73	0.38	0.45	0.64	0.25

Note: The CF refers to counterfactual, GR refers to gender ratio, and MPS refers to the "male–past sex" distribution. Counterfactuals set the black gender ratios and male–past sex distributions equal to those of whites. Each cell gives the probability of matching in sex or no-sex markets based on an individual's grade and possible partner grade. The P_m^w is the probability of matching for a man looking for a woman; P_w^m is the probability of matching for a woman looking for a man.

can triple his probability of matching by searching in the no-sex market. The next two rows (CF Only GR) report on the simulation where blacks face the same grade-specific gender ratios as whites. This change increases (decreases) the probabilities of matching in all markets for females (males), but not uniformly. Consistent with Proposition 1, the percentage increase in the probability of matching is higher for women in the market that they prefer: the no-sex market. This translates into women changing their search behavior and results in a greater share of matches occurring in the no-sex market.

The last two rows (CF GR-MPS) show how the probabilities change when we additionally adjust the past-sex distributions for black males to match those with white males. By reducing the number of sexually experienced black men, competition among men in the sex market is reduced. This increases the match probabilities of black men searching in the sex market and correspondingly decreases the match probabilities of black men searching in the no-sex market. The opposite changes occur for women: as compared to the case where just the gender ratio was changed, women see higher match probabilities in the no-sex market and lower match probabilities in the sex market. With fewer black men having had sex in the past, demand decreases in the sex market, lowering female probabilities of matching there and correspondingly increasing female probabilities of matching in the no-sex market.

Table 15 captures how these changes in the probabilities of matching translate into changes in the fraction of relationships with sexual engagement. For expositional reasons we report a racial gap in sexual engagement for same-grade and same-race matches only.[35] The "racial gap" compares probabilities of having sex *conditional on matching*. Table 15 reports the difference between these conditional probabilities for

Table 15. Racial gap in the probability of sex conditional matching under various market conditions.

	Same Type $P(\text{sex}\mid\text{match})$			
Aggregate School	9	10	11	12
White	0.210	0.393	0.537	0.648
Black	0.312	0.497	0.644	0.741
Difference	−0.102	−0.105	−0.106	−0.093
Changing				
Only gender ratios				
White	0.209	0.393	0.537	0.648
Black	0.298	0.491	0.638	0.738
Difference	−0.088	−0.099	−0.101	−0.090
Gender ratios and male past sex				
White	0.209	0.393	0.538	0.648
Black	0.274	0.431	0.573	0.672
Difference	−0.065	−0.038	−0.035	−0.024

Note: Gap is measured as $P(\text{sex}\mid\text{match, white with white}) - P(\text{sex}\mid\text{match, black with black})$. Counterfactual policy simulation changes the black gender ratios to match those of whites in three stages: changing the grade-specific gender ratio, then the past-sex distribution for black males, and then the past-sex distribution for both black females and black males.

[35] Results look similar within a partner–grade category.

whites matched with whites minus that for blacks matched with blacks. The baseline shows the 9–10 percentage point racial gap noted earlier. When we simulate (i) blacks facing the same grade-specific gender ratios as whites, the gap shrinks, particularly for younger couples, but the effects are small. Additionally adjusting the past-sex distribution for black men (ii) yields a much larger effect, between 65% and 75% of the gap for 10th–12th graders.

7. Conclusion

The contribution of this paper is twofold. First, we show how a directed search model can disentangle male and female preferences for different relationship terms using variation in the gender ratio. When the researcher's goal is to understand differences in male and female preferences for relationship terms, directed search provides an attractive modeling approach.

Second, we have applied the directed search model to the teen matching market and uncovered male and female differences in preferences for sex. The estimated preferences from the structural model match the self-reported preferences, providing a compelling out-of-sample test for the validity for the approach. That men and women value sex differently suggests that changes in sexual behaviors may have different welfare effects for men than for women. Further, when gender ratios tilt such that men become a minority—as, for example, on many college campuses—women are more likely to engage in sex conditional on forming a relationship, sacrificing their preferred relationship terms for a higher probability of matching.

Our counterfactual simulations show that, conditional on matching, most of the gap in sexual engagement between black and white women in high school is driven by the unfavorable market conditions that black women face. If conditions faced by blacks (as measured by the gender ratio and sexual experience of males) were similar to those for whites, the racial gap in sexual participation would shrink between 65% and 75% for 10th–12th graders.

More generally, because changes in the supplies of various types of men and women alter the equilibrium match distribution, such changes have the potential to deeply affect the well-being of individuals—changing who enters unions of many types, who does not enter at all, the characteristics of partners for those who do match, and the distribution of surplus from unions among partners. These important links are reflected in a growing literature on the effects of imbalances and changes in sex ratios within both developed and developing countries. Many of these studies focus on the effects of changing sex ratios on who does and does not enter unions and with whom those who enter match.[36] Other studies address the partial equilibrium effects on the intra-union distribution of the match surplus.[37] But the methods in these studies cannot reveal the separate preferences of men and women and how the trade-offs they face relate to the supplies of various types of men and women. Our model and empirics take a step in that direction.

[36] Examples include Wilson (1987), Willis (1999), Abramitzky, Delavande, and Vasconcelos (2011), and Rose (2004)

[37] See Chiappori, Oreffice, and Quintana-Domeque (2012) and Bruze, Svarer, and Weiss (2015).

Appendix A

Proof of Proposition 1. The proof of claim (a) follows from manipulating the definition of the search probability. Assuming $\mu_w^{mr'} - \mu_w^{mr} > \mu_m^{wr'} - \mu_m^{wr}$, we can add the log match probability for each combination to both sides in the manner

$$\begin{aligned}&\mu_w^{mr'} + \log(P_w^{mr'}) - \mu_w^{mr} - \log(P_w^{mr}) + \log(P_m^{wr'}) - \log(P_m^{wr})\\&\quad > \mu_m^{wr'} + \log(P_m^{wr'}) - \mu_m^{wr} - \log(P_m^{wr}) + \log(P_w^{mr'}) - \log(P_w^{mr}).\end{aligned}$$

Exponentiating both sides gives us a ratio of choice probabilities and match probabilities because the choice probabilities share the same denominator:

$$\frac{e^{\mu_w^{mr'}+\log(P_w^{mr'})}}{e^{\mu_w^{mr}+\log(P_w^{mr})}} e^{\log(P_m^{wr'})-\log(P_m^{wr})} > \frac{e^{\mu_m^{wr'}+\log(P_m^{wr'})}}{e^{\mu_m^{wr}+\log(P_m^{wr})}} e^{\log(P_w^{mr'})-\log(P_w^{mr})}$$

or

$$\frac{\phi_w^{mr'}}{\phi_w^{mr}} \frac{P_m^{wr'}}{P_w^{mr'}} > \frac{\phi_m^{wr'}}{\phi_m^{wr}} \frac{P_m^{wr}}{P_w^{mr}}.$$

Now note that the ratio of match probabilities can be expressed as

$$\frac{P_m^{wr'}}{P_w^{mr'}} = \frac{\left[1 + \left(\dfrac{\phi_w^{mr'} N_w}{\phi_m^{wr'} N_m}\right)^{\rho}\right]^{1/\rho}}{\left[1 + \left(\dfrac{\phi_m^{wr'} N_m}{\phi_w^{mr'} N_w}\right)^{\rho}\right]^{1/\rho}} = \frac{\left[\left(\dfrac{\phi_m^{wr'} N_m}{\phi_m^{wr'} N_m}\right)^{\rho} + \left(\dfrac{\phi_w^{mr'} N_w}{\phi_m^{wr'} N_m}\right)^{\rho}\right]^{1/\rho}}{\left[\left(\dfrac{\phi_w^{mr'} N_w}{\phi_w^{mr'} N_w}\right)^{\rho} + \left(\dfrac{\phi_m^{wr'} N_m}{\phi_w^{mr'} N_w}\right)^{\rho}\right]^{1/\rho}},$$

which by canceling the numerators inside both matching functions simplifies to

$$\frac{P_m^{wr'}}{P_w^{mr'}} = \left[\left(\frac{\phi_w^{mr'} N_w}{\phi_m^{wr'} N_m}\right)^{\rho}\right]^{1/\rho}.$$

Imposing the same equality in the r market and substituting into the inequality, we have

$$\frac{\phi_w^{mr'}}{\phi_w^{mr}} \left[\left(\frac{\phi_w^{mr'} N_w}{\phi_m^{wr'} N_m}\right)^{\rho}\right]^{1/\rho} > \frac{\phi_m^{wr'}}{\phi_m^{wr}} \left[\left(\frac{\phi_w^{mr} N_w}{\phi_m^{wr} N_m}\right)^{\rho}\right]^{1/\rho},$$

which further simplifies to

$$\left(\frac{\phi_w^{mr'}}{\phi_w^{mr}}\right)^2 > \left(\frac{\phi_m^{wr'}}{\phi_m^{wr}}\right)^2,$$

and claim (a) follows since the choice probabilities are always positive.

Claim (b) follows from claim (a) and $\rho < 0$. Given claim (a) we have

$$\frac{\phi_w^{mr}}{\phi_m^{wr}} < \frac{\phi_w^{mr'}}{\phi_m^{wr'}}:$$

multiplying both sides by N_w/N_m and raising both sides to the $1/\rho$ power flips the inequality,

$$\left(\frac{\phi_w^{mr} N_w}{\phi_m^{wr} N_m}\right)^{1/\rho} > \left(\frac{\phi_w^{mr'} N_w}{\phi_m^{wr'} N_m}\right)^{1/\rho};$$

adding 1 to both sides and raising both to the power ρ switches the inequality once more and we have

$$\left[1 + \left(\frac{\phi_w^{mr} N_w}{\phi_m^{wr} N_m}\right)^{1/\rho}\right]^{\rho} < \left[1 + \left(\frac{\phi_w^{mr'} N_w}{\phi_m^{wr'} N_m}\right)^{1/\rho}\right]^{\rho},$$

which is the definition of $P_m^{wr} < P_m^{wr'}$. Beginning with the inequality between the ratio of choice probabilities with female choice probabilities in the denominator delivers the result for female match probabilities.

To evaluate claim (c), we use the implicit function theorem coupled with Cramer's rule. We show the case when there is only one type of man and one type of woman with two relationship types, r and r'. For ease of notation, we then denote $G = G_r^m$. Our proof, however, holds in the general case due to the independence of irrelevant alternatives associated with the type I extreme value errors. Note that the definitions of search probabilities imply that, in equilibrium, the log odds ratios for women satisfy

$$\begin{aligned} &\ln(\phi_w^{mr'}) - \ln(1 - \phi_w^{mr'}) \\ &\quad \equiv \ln(\mu_w^{mr'}) - \ln(\mu_w^{mr}) + \ln\left[1 + \left(\frac{\phi_m^{wr'} G}{\phi_w^{mr'}}\right)^{\rho}\right] - \ln\left[1 + \left(\frac{(1 - \phi_m^{wr'})G}{1 - \phi_w^{mr'}}\right)^{\rho}\right]. \end{aligned} \tag{15}$$

Now, for men and women respectively, define:

$$\begin{aligned} F_1(\phi_w^{mr'}, \phi_m^{wr'}, G) &\equiv \ln(\phi_w^{mr'}) - \ln(1 - \phi_w^{mr'}) - \ln(\mu_w^{mr'}) + \ln(\mu_w^{mr}) \\ &\quad - \ln\left[1 + \left(\frac{\phi_m^{wr'} G}{\phi_w^{mr'}}\right)^{\rho}\right] + \ln\left[1 + \left(\frac{(1 - \phi_m^{wr'})G}{1 - \phi_w^{mr'}}\right)^{\rho}\right], \\ F_2(\phi_w^{mr'}, \phi_m^{wr'}, G) &\equiv \ln(\phi_m^{wr'}) - \ln(1 - \phi_m^{wr'}) - \ln(\mu_m^{wr'}) + \ln(\mu_m^{wr}) \\ &\quad - \ln\left[1 + \left(\frac{\phi_w^{mr'}}{\phi_m^{wr'} G}\right)^{\rho}\right] + \ln\left[1 + \left(\frac{1 - \phi_w^{mr'}}{(1 - \phi_m^{wr'})G}\right)^{\rho}\right], \end{aligned}$$

which can equivalently be expressed as

$$\begin{aligned} &F_1(\phi_w^{mr'}, \phi_m^{wr'}, G) \\ &\quad \equiv 2\ln(\phi_w^{mr'}) - 2\ln(1 - \phi_w^{mr'}) - \ln(\mu_w^{mr'}) + \ln(\mu_w^{mr}) \\ &\qquad - \ln\left[(\phi_w^{mr'})^{\rho} + (\phi_m^{wr'} G)^{\rho}\right] + \ln\left[(1 - \phi_w^{mr})^{\rho} + ((1 - \phi_m^{wr'})G)^{\rho}\right], \end{aligned}$$

$$
\begin{aligned}
&F_2\big(\phi_w^{mr'}, \phi_m^{wr'}, G\big) \\
&\quad \equiv 2\ln\big(\phi_m^{wr'}\big) - 2\ln\big(1-\phi_m^{wr'}\big) - \ln\big(\mu_m^{wr'}\big) + \ln\big(\mu_m^{wr}\big) \\
&\qquad - \ln\biggl[\big(\phi_m^{wr'}\big)^\rho + \left(\frac{\phi_w^{mr'}}{G}\right)^\rho\biggr] + \ln\biggl[\big(1-\phi_m^{wr'}\big)^\rho + \left(\frac{1-\phi_w^{mr'}}{G}\right)^\rho\biggr].
\end{aligned}
$$

Taking the total derivative of the identities implies from the implicit function theorem that

$$
\begin{bmatrix} \dfrac{\partial F_1}{\partial \phi_w^{mr'}} & \dfrac{\partial F_1}{\partial \phi_m^{wr'}} \\ \dfrac{\partial F_2}{\partial \phi_w^{mr'}} & \dfrac{\partial F_2}{\partial \phi_m^{wr'}} \end{bmatrix} \begin{bmatrix} \dfrac{\partial \phi_w^{mr'}}{\partial G} \\ \dfrac{\partial \phi_m^{wr'}}{\partial G} \end{bmatrix} = - \begin{bmatrix} \dfrac{\partial F_1}{\partial G} \\ \dfrac{\partial F_2}{\partial G} \end{bmatrix}
$$

holds, which can be expressed as

$$
\begin{bmatrix} \dfrac{\partial \phi_w^{mr'}}{\partial G} \\ \dfrac{\partial \phi_m^{wr'}}{\partial G} \end{bmatrix} = - \begin{bmatrix} \dfrac{\partial F_1}{\partial \phi_w^{mr'}} & \dfrac{\partial F_1}{\partial \phi_m^{wr'}} \\ \dfrac{\partial F_2}{\partial \phi_w^{mr'}} & \dfrac{\partial F_2}{\partial \phi_m^{wr'}} \end{bmatrix}^{-1} \begin{bmatrix} \dfrac{\partial F_1}{\partial G} \\ \dfrac{\partial F_2}{\partial G} \end{bmatrix}.
$$

The partial derivatives of F_1 and F_2 with respect to G can be expressed as

$$
\begin{aligned}
\frac{\partial F_1}{\partial G} &= G^{-1}\left(\left[\left(\frac{1-\phi_w^{mr'}}{\big(1-\phi_m^{wr'}\big)G}\right)^\rho + 1\right]^{-1} - \left[\left(\frac{\phi_w^{mr'}}{\phi_m^{wr'} G}\right)^\rho + 1\right]^{-1}\right), \\
\frac{\partial F_2}{\partial G} &= G^{-1}\left(\left[\left(\frac{\phi_m^{wr'} G}{\phi_w^{mr'}}\right)^\rho + 1\right]^{-1} - \left[\left(\frac{\big(1-\phi_m^{wr'}\big)G}{1-\phi_w^{mr'}}\right)^\rho + 1\right]^{-1}\right).
\end{aligned}
$$

Since $\rho < 0$ and (by claim (a)) $\frac{1-\phi_w^{mr'}}{1-\phi_m^{wr'}} = \frac{\phi_w^{mr}}{\phi_m^{wr}} < \frac{\phi_w^{mr'}}{\phi_m^{wr'}}$, both $\partial F_1/\partial G$ and $\partial F_2/\partial G$ are greater than 0.

The partial derivatives of F_1 and F_2 with respect to $\phi_w^{mr'}$ and $\phi_m^{wr'}$ can be expressed as

$$
\begin{aligned}
\frac{\partial F_1}{\partial \phi_w^{mr'}} &= \frac{\big(\phi_w^{mr'}\big)^\rho + 2\big(\phi_m^{wr'} G\big)^\rho}{\phi_w^{mr'}\big(\big(\phi_w^{mr'}\big)^\rho + \big(\phi_m^{wr'} G\big)^\rho\big)} \\
&\quad + \frac{\big(1-\phi_w^{mr'}\big)^\rho + 2\big(\big(1-\phi_m^{wr'}\big)G\big)^\rho}{\big(1-\phi_w^{mr'}\big)\big(\big(1-\phi_w^{mr'}\big)^\rho + \big(\big(1-\phi_w^{mr'}\big)G\big)^\rho\big)} > 0, \\
\frac{\partial F_1}{\partial \phi_m^{wr'}} &= -\frac{\big(\phi_m^{wr'} G\big)^\rho}{\phi_m^{wr'}\big(\big(\phi_w^{mr'}\big)^\rho + \big(\phi_m^{wr'} G\big)^\rho\big)} \\
&\quad - \frac{\big(\big(1-\phi_m^{wr'}\big)G\big)^\rho}{\big(1-\phi_m^{wr'}\big)\big(\big(1-\phi_w^{mr'}\big)^\rho + \big(\big(1-\phi_w^{mr'}\big)G\big)^\rho\big)} < 0,
\end{aligned}
$$

$$\frac{\partial F_2}{\partial \phi_w^{mr'}} = -\frac{(\phi_w^{mr'})^\rho}{\phi_w^{mr'}((\phi_w^{mr'})^\rho - (\phi_m^{wr'}G)^\rho)} - \frac{(1-\phi_w^{mr'})^\rho}{(1-\phi_w^{mr'})((1-\phi_w^{mr'})^\rho + ((1-\phi_w^{mr'})G)^\rho)} < 0,$$

$$\frac{\partial F_2}{\partial \phi_m^{wr'}} = \frac{2(\phi_w^{mr'})^\rho + (\phi_m^{wr'}G)^\rho}{\phi_m^{wr'}((\phi_w^{mr'})^\rho + (\phi_m^{wr'}G)^\rho)} + \frac{2(1-\phi_w^{mr'})^\rho + ((1-\phi_m^{wr'})G)^\rho}{(1-\phi_m^{wr'})((1-\phi_w^{mr'})^\rho + ((1-\phi_w^{mr'})G)^\rho)} > 0.$$

Appealing to Cramer's rule,

$$\frac{\partial \phi_w^{mr'}}{\partial G} = \frac{\dfrac{\partial F_1}{\partial G}\dfrac{\partial F_2}{\partial \phi_m^{wr'}} - \dfrac{\partial F_1}{\partial \phi_m^{wr'}}\dfrac{\partial F_2}{\partial G}}{\dfrac{\partial F_1}{\partial \phi_w^{mr'}}\dfrac{\partial F_2}{\partial \phi_m^{wr'}} - \dfrac{\partial F_1}{\partial \phi_m^{wr'}}\dfrac{\partial F_2}{\partial \phi_w^{mr'}}},$$

$$\frac{\partial \phi_w^{mr'}}{\partial G} = \frac{\dfrac{\partial F_2}{\partial G}\dfrac{\partial F_1}{\partial \phi_w^{mr'}} - \dfrac{\partial F_2}{\partial \phi_w^{mr'}}\dfrac{\partial F_1}{\partial G}}{\dfrac{\partial F_1}{\partial \phi_w^{mr'}}\dfrac{\partial F_2}{\partial \phi_m^{wr'}} - \dfrac{\partial F_1}{\partial \phi_m^{wr'}}\dfrac{\partial F_2}{\partial \phi_w^{mr'}}}.$$

In both cases, the numerators are positive. Both have one negative term, $\partial F_1/\partial \phi_m^{wr'}$ and $\partial F_2/\partial \phi_w^{mr'}$, respectively, but this term is multiplied by negative 1.

The denominators are the same across the two expressions. The first term is positive but the second term is negative. However, the first term can be written as the negative of the second term plus additional positive terms. The sign of the denominator is then positive, implying that both expressions are positive as well. □

Appendix B

In this appendix we discuss three issues with the data: (i) determining the share of students searching in the outside market, (ii) determining the distribution of prior sex for males, and (iii) cases where females do not report characteristics of their partners.

To deal with the unobserved aggregate fraction searching outside the school, we begin with a strong assumption and subsequently relax it. We assume initially that each individual could match outside the school with probability 1. This means that we only need the fraction of each individual type matching outside the school to correct the aggregate gender ratios to reflect the number of men and women of each type searching in the school. Using data on individuals who matched outside the school, those unmatched and those matched in the school, we estimate a logit on matching outside the school that is a function of individual grade, race, and school fixed effects, and we do so separately for men and women. For example, we specify the probability of matching outside the school for an m-type man at school s as

$$P(\text{match out}|m,s)=\frac{\exp\left(\sum_g I(G_m=g)\gamma_g+\sum_r I(R_m=r)\gamma_r+\gamma_s\right)}{1+\exp\left(\sum_g I(G_m=g)\gamma_g+\sum_r I(R_m=r)\gamma_r+\gamma_s\right)}. \tag{16}$$

The resulting predicted conditional probabilities are used to scale down the number of searching men m and searching women w within each school.

We subsequently relax the perfect ability to match outside the school by imposing that each match observed required more individuals searching outside the school so as to materialize. For example, if we see that one male of type m matched outside the school, assuming the probability of matching outside was one-half, we would reduce the number of type-m men searching in the school by 2.

To deal with the unobserved distribution of male past sexual activity from using female reports, we estimate the conditional probability of past sex at the school level from the male half of the original sample. We do this only among those who are not matched outside the school; thus we specify the probability of past sex for an m-type man at school s as

$$\begin{aligned}
&P(\text{past sex}|m,s,\text{match out}=0)\\
&\quad=\frac{\exp\left(\sum_g I(G_m=g)\theta_g+\sum_r I(R_m=r)\theta_r+\theta_s\right)}{1+\exp\left(\sum_g I(G_m=g)\theta_g+\sum_r I(R_m=r)\theta_r+\theta_s\right)}\\
&\quad=\pi^s_{m1},
\end{aligned} \tag{17}$$

again using grade, race, and school fixed effects. These predicted conditional probabilities are used as weights to integrate out the number of men searching in each market.

The next data issue concerns missing reports on partner characteristics. Because of the likelihood approach it is straightforward to take what information we do observe from reports on the partner characteristics and terms, and form likelihood terms that integrate out over the missing data, very similar to how we integrate out over missing search decisions in equation (11).

Appendix C

In this appendix we demonstrate the robustness of our estimation strategy to misspecification of the probability of matching outside the school. In our approach we estimate the probability of matching outside the market as in Appendix B, as a function of type, gender, and school fixed effects, but that model may be misspecified.

Table C.1. Monte Carlo experiment.

		Information Structure					
		Full		Partial I		Partial II	
	Truth	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.
ρ	−1.650	−1.657	(0.718)	−1.560	(0.817)	−1.781	(1.023)
A	0.400	0.400	(0.022)	0.397	(0.023)	0.403	(0.030)
σ^{-1}	0.500	0.559	(0.177)	0.573	(0.200)	0.562	(0.221)
F_{sex}	−2.250	−2.302	(0.764)	−2.428	(0.717)	−2.492	(1.075)
M_{sex}	2.000	2.074	(0.705)	1.984	(0.519)	2.266	(1.028)
F partner old	3.250	3.292	(0.989)	3.197	(0.944)	3.565	(1.567)
M partner old	−2.000	−1.963	(0.650)	−2.052	(0.613)	−2.330	(1.284)
F partner minority	−1.300	−1.272	(0.342)	−1.250	(0.404)	−1.423	(0.652)
M partner minority	4.250	4.337	(1.243)	4.391	(1.338)	4.609	(2.019)
Avg male $P(\text{match out})$		0.209		0.209		0.342	
Avg female $P(\text{match out})$		0.351		0.351		0.501	
$P(\text{out misspecified})$		No		Yes		Yes	

Note: The term $P(\text{out})$ is a function of type–gender ratio and their interaction; $P(\text{out})$ misspecified is only a function of the gender ratio and type. Results are based on averaging 10 simulations.

In our Monte Carlo we generate the probability of matching outside the school as a function of the type–gender ratio and their interaction. This is the form of misspecification that is the most problematic, as it would invalidate the two-step approach we take above (separating out-matching into a first stage, followed by within-school matching), by making the first stage a function of gender ratio differently for different types. We examine how the estimator responds when we omit the interaction term. The results for 50 simulations are presented in Appendix Table C.1, where we only include two binary characteristics and one binary term. The results when we correctly specify the probability of matching outside the school are presented under the "Information Structure: Full" columns. As we can see the estimator preforms well. The large standard errors arise when we remove the search decisions (results not presented), but point estimates are still close to the truth. In the "Partial I" and "Partial II" columns we incorrectly specify the probability of matching out, omitting the type–gender ratio interactions, but at different overall and gender-specific levels. The results reveal that as out-matching becomes more prevalent, our standard errors grow substantially (e.g., the sex preferences) and point estimates move farther from the truth. The partner characteristic estimates are more biased because individuals with certain characteristics are more likely to search outside the school (e.g., older minority females match out at the highest rates), which is mistakenly attributed to nonmatching under misspecification. The outmatching rates we observe in the data are quite similar to those in the "Partial I" exercise (in the 20%–30% range), where the level of bias is quite reasonable (less than 10% for all parameters).

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