Modeling Mate-Choice using Computational Temperature and Dynamically Evolving Representations

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Abstract

We present a model of mate-choice (KAMA) that is based on a gradual, stochastic process of representation-building leading to marriage. KAMA reproduces empirically verifiable population-level mate-selection behavior using individual-level mate-choice mechanisms. Individuals have character profiles, which describe a number of their characteristics (physical beauty, potential earning power, etc.), as well as preference profiles, that specify their degree of preference for those characteristics in members of the opposite sex. A process of encounters and dating serves to exchange information and allows accurate representations of potential mates to be gradually built up over time. Finally, individuals each have a "temperature", which is the extent to which they are willing to continue exploring mate-space. "Temperature" (the inverse of mate "choosiness") drives individual decision-making in this model. We show that the individual-level mechanisms implemented in the model produce population-level data that qualitatively matches empirical data.

Introduction

We present a preliminary model of mate-choice that is based on a gradual, stochastic process of representation-building leading to marriage. Our model, KAMA, attempts to reproduce empirical population-level mate-selection behavior based on mate-choice mechanisms implemented at the level of individuals in the population. Our model involves the interplay of a number of simple, competing pressures and constraints. Specifically, given a host of physical constraints, individuals must attempt,:

i) to find as good a mate as possible, given a host of physical constraints,
ii) in a limited amount of time
iii) with only partial knowledge of the individuals in the pool of potential candidates

The process of encounters and dating allows individuals to gradually build up more accurate representations of other individuals in that population. Since there is insufficient time to go through the whole mate pool and gather complete information of the characteristics of all potential mates, mate-choice decisions are necessarily based on partial information (e.g., Miller & Todd, 1998).

We hope to show that a limited number of relatively simple mechanisms at the individual level are sufficient to enable individuals to match up appropriately and, in so doing, generate realistic (i.e. similar to those found in the empirical literature) population-level behavior (Simao & Todd, 2003; Todd, Billari & Simao, 2005). We develop a model of mate-choice that differs with respect to current mate-choice models in four major respects — namely:

i) it incorporates context-dependent computational temperature as a measure (actually, the inverse) of mate-choosiness (Jennions & Petrie 1997);
ii) it uses a multi-dimensional vector of values associated with a number of characteristics, instead of a single mate-value describing each individual;
iii) it employs a fluid representational structure for potential mates, allowing the representation of an individual to evolve over time as new information about that person becomes available;
iv) it uses subjective mate-values, since mate-value is largely, although not completely, subjective ("beauty is in the eye of the beholder") incorporating empirical findings on male-female preference profiles for various characteristics found in their mates (Buss & Barnes, 1986).

This model qualitatively reproduces empirical data on first-marriage hazard rates at various ages, male/female marriage-age shifts (women initially marry earlier than men), and changes in marriage-rate curves when pressure to marry early is decreased. We will, in addition, briefly compare the performance of KAMA to a family of models developed by Todd and colleagues (Todd, Billari & Simão, 2005).

Mate-value: Preference-weighted character profiles

The standard means of quantifying attractiveness in the context of mate-choice is by a single mate-value. The higher an individual's mate-value, the more likely he or she is to have reproductive success (Ellis, 1992). We have chosen to model mate-value somewhat differently. First, in contrast to previous models — in particular, Simão and Todd (2001, 2002, 2003) — we assume a multi-dimensional characterization of each individual in the population. There are 13 distinct attributes (plus age) that characterize each individual in the population and each of these attributes has a value. We call this set of 13 values, the individual's *character profile*.

In addition, each individual has a *preference profile* that specifies how much weight he or she attaches to each attribute in the character-profile of a mate of the opposite sex (Buss and Barnes, 1986). Individuals having different

preference-profiles means that perceived mate-value is not the same across all individuals in the population.

A weighted linear model is assumed for integrating the characteristics into the mate-value. The mate-value then of a potential mate, Y, for an individual, X, is computed by averaging the inner product of X's preference profile and Y's character profile.

Buss and Barnes (1986) studied mate-preferences in males and females. Their findings showed that, in spite of significant individual differences, there were certain trends in the characteristics that males and females valued. In a further study, Buss also claimed that preferences for at least 60% of these characteristics were universal (Buss, 1989). We translated Buss and Barnes's table of preference rankings into preference weights. (We made the assumption of a normal distribution about each mean, from which we draw values when creating individuals.)

This leads to asymmetric preferences in the men and women modeled in our simulation. For example, Buss & Barnes (1986) found that men put considerably more emphasis on "physical attractiveness" than women, whereas women place more emphasis on "having a college education" and "having a good earning capacity."

A final departure from other models of mate-choice is that the true mate-value of potential mates is revealed only gradually, corresponding to the notion that it takes time to get to know a potential mate. (Until the value of a particular attribute is known through encounters with the potential mate, a default value is used.)

To reiterate, all individuals maintain a memory of their recent dating experience with other individuals in the population. Mate information (i.e., an individual's representations of other potential mates in the population) improves gradually over time as a function of the number of contacts between two individuals. Gradual representation-building — as opposed to static mate-values which are displayed for all to see, as in previous mate-choice models — plays a crucial role in the present model. The current model's reliance on a multi-dimensional mate value for each individual, on observer-dependent (i.e., subjective) mate-values, and gradual representation-building are unique to the current model.

Search strategies

Individuals in the present model explore the mate pool by means of a parallel exploration strategy – the so-called parallel terraced scan (Hofstadter, 1984) – that gradually becomes more and more focused on those individuals of the opposite sex with the highest mate values who are willing to go out with them. The willingness of an individual to proceed with this search depends on an internal parameter called *temperature*. (Hofstadter, 1984, Hofstadter et al., 1995, proposed the related notions of a parallel terraced scan and context-dependent computational temperature in the context of the modeling of analogy-making. Further development of these notions can be found in Mitchell, 1993 and French, 1995. N.B.: This differs from the notion of temperature in the simulated annealing of Kirkpatrick et al. (1983) in that there is no pre-set annealing schedule.) Temperature — the inverse of "mate-choosiness" (Jennions & Petrie, 1997) — is a measure that depends both on an individual's recent dating history and his/her age. The higher the temperature, the more willing an individual is to explore the space of potential mates; the lower the temperature, the less willing – generally meaning that he/she is concentrating on one particular relationship, largely to the exclusion of others. When both individuals in a dating relationship have low enough temperatures, "marriage" occurs and they drop out of the mate pool.

The model is also *stochastic,* meaning that essentially all choices are made probabilistically. So, for example, if one potential mate has an overall mate-value of 8, and another a mate-value of 5, the first will not automatically be chosen. The latter will also have a chance – under some circumstances, even essentially equal to that of the first individual – of being chosen.

Males ask, females choose

Darwin (1859, 1871) observed that, in general, in nature the female makes the final mating decision. Males display themselves ostentatiously before a female in order to be chosen as her mate. We assume a similar mate-choice asymmetry in our model. The male selects someone to ask out among a number of alternatives; the female then accepts or declines his invitation immediately upon receiving it. This necessarily implies that her strategy for accepting or refusing a date proposition is different from the male's "parallel" strategy for deciding whom to ask out among a number of alternatives.

A run of the program

A run of the simulation starts with 600 individuals (300 males, 300 females) whose ages vary randomly between 18 and 48. Unmarried individual who turn 49 are removed from the population and replaced with an 18 year-old of the same sex with default characteristic values. In addition, a number of individuals amounting to 5% of the total population are added to the population each "year." Each year has 52 "weeks" and the program stops after running for 60 years.

At the beginning of each week, 60% of the males encounter between 1 and 3 randomly chosen females (depending on the male's "temperature" – see below) and exchange a limited amount of information with the individuals they encounter. Each male maintains a list of all previously encountered females. If he encounters a female already on his list, he updates his representation of her. If a recently encountered female has a particularly good mate value, she will be put on his list of 5 "potentially datable" females. He then considers which of the potentially datable females to ask out for a date. This probabilistic decision (see below) is based on the temperature-biased (subjective) mate-value of each of the females on his list of potentially datable females list. If the female he asks out immediately either accepts or refuses his offer. The female makes her decision based on her (temperature-biased) evaluation of the proposing male's mate-value, relative to that of other males she has recently dated (see below).

After acceptance or refusal of a date, the temperature of the individuals involved is updated. If the temperature of both the man and woman on a date is below a (pre-set) threshold value, they marry and leave the population. All unmarried individuals repeat the encounter-dating-marriage cycle until 60 years have passed.

Date proposal and date acceptance/refusal

Males ask females out and females accept or decline their offers. The details of these two distinct strategies are as follows.

Asking for a date (males)

The male's decision to ask a particular female out is based on his subjective perception of her mate-value (i.e., based on his own preference profile) biased by his current temperature (the inverse of choosiness). Individual females with higher subjective mate-values have, in general, a higher probability of being chosen (unless the male's temperature is very high – i.e., choosiness very low – in which case, the choice is essentially a uniform random one). The level of choosiness makes the process of choosing a female more or less discriminating. Assuming that the subset of females to pick from is the last R females either encountered or dated (i.e, contacts), the probability that $Male_i$ will ask out $Female_j$ is calculated as follows:

$$P_{ij} = \frac{(MV_j)^{Ch_i}}{\sum_{n=1}^{R}(MV_{j_n})^{Ch_i}}$$

where:
P_{ij} is the probability of $Male_i$ asking $Female_j$ out
MV_j is the mate-value of *Female j*
R is the total number of recent contacts by $Male_i$
j_n are the indices of the R potentially datable females,
Ch_i is the choosiness of *Male i.* (i.e., $Ch_i = 1/T_i$).

Note that when Ch_i is 1 (the normal default level of choosiness), then the probability of selecting of a potential mate is her mate-value divided by the sum of the mate-values of the 5 females on the male's list of potentially datable females. However, if the choosiness value becomes very low (i.e., temperature very high: "I don't care who I ask out, as long as I ask someone for a date."), then selection is essentially independent of mate-value: any candidate is equally likely to be chosen. If, on the other hand, choosiness, Ch_i, is high (i.e., temperature low: "I want to be sure to ask out *only* the woman with the highest mate-value"), then the temperature equation will ensure that the highest mate-value will completely dominate the other values and the female with this value will be chosen with an extremely high probability, i.e., essentially deterministically.

Figure 1 gives a simple example of how the temperature mechanism works. Assume there are three potential candidates to pick from, having raw mate-values of 2, 3, of 5. So, even though the raw mate-value of F_3 remains unchanged, the probability of selection of F_3 goes from 1/3 (high temperature, i.e., not choosy at all) to 0.92 (low temperature; i.e., very choosy).

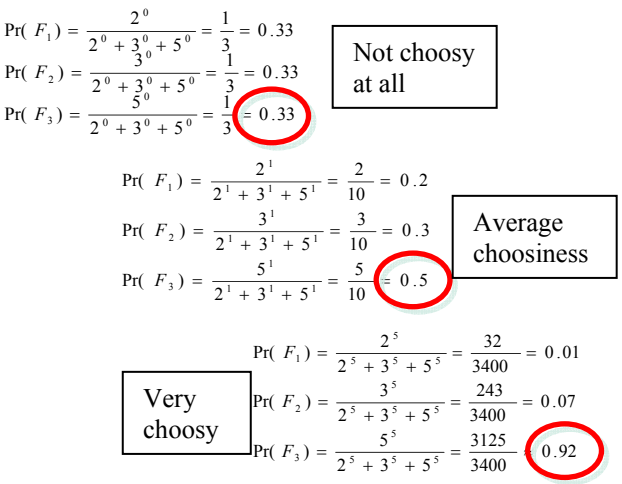

Figure 1. From random selection to quasi-deterministic selection of F_3 depending on temperature.

Accepting/rejecting an offer (females)

A male has asked a particular female out. She must now decide whether or not to accept his offer. She cannot postpone her reply and choose among many offers. She must say yes or no to the current offer immediately. This requires a different decision-making procedure than the "parallel" (i.e., choice among many) procedure used by the male to decide whom to ask out. Her stochastic decision mechanism is as follows:

Each female has a record of the mate-values of her previous dates. The mean and variance of these mate-values are used to calculate a normal distribution, which provides her with a rough estimate of the distribution of mate-values of the kind of males likely to ask her out. It also allows her to situate her potential suitor with respect to other males she has gone out with in the past. Thus, where her new suitor's mate-value falls on this normal curve will determine her probability of accepting a date with him (Figure 2).

The proposing male has an unadjusted subjective mate-value that must now be adjusted based on the female's level of choosiness. If she is very choosy (she is already seeing a great guy regularly and only a real superstar will interest her), she will adjust his MV to fall to the left of where it normally would fall, thus decreasing her probability of accepting his offer. If, on the other hand, she is not particularly choosy (she just wants to have a date on Friday night), she will adjust her suitor's mate-value upwards, thereby increasing the probability of her accepting his offer.

The temperature-adjusted mate-value of her suitor is calculated as follows:

$$MV'_i = MV_i + k\log(T_j)$$

where: MV'_i is the adjusted mate-value of her suitor, $Male_i$

MV_i is the unadjusted mate-value of her suitor, $Male_i$

T_j is the Temperature of $Female_j$ who was asked out

k is a constant

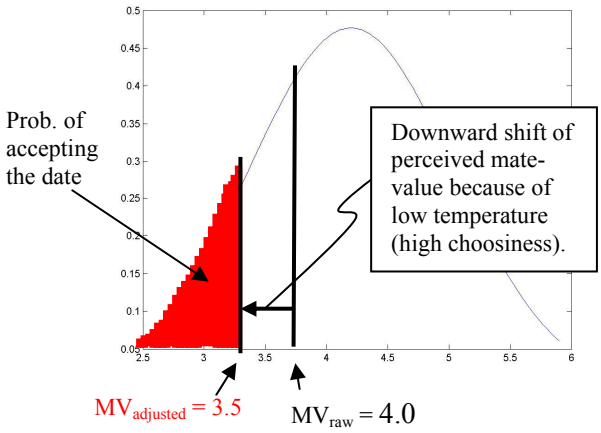

Figure 2. The female adjusts mate-value as a function of temperature.

The idea is that when the female's choosiness is high (i.e., low temperature, T<1), the perceived mate-value of a potential suitor shifts downward, making it less likely for her to accept a date offer by him. Adding *k*log(*T*) to the original mate-value when T < 1 decreases the original mate-value and makes it less likely for her to accept a date proposition; when T >1, adding this factor increases the original mate-value, making it more likely for her to accept his proposition.

Choosiness – Computational Temperature

Each individual has a context-dependent computational temperature. As we have seen, temperature corresponds exactly to the inverse of an choosiness in mate-search and mate-selection. The lower the temperature, the higher the individual's choosiness and vice-versa. Temperature is affected by two factors — namely:

- Age of the individual
- Length of current relationship (i.e., number of dates with the same individual)

The underlying assumption of the age factor of temperature is that, initially, in one's late teens and early 20's, there is a considerable expenditure in time and energy to meet members of the opposite sex (a fact that hardly needs documentation!). This then falls as one becomes involved in other pursuits, principally career pursuits, and then gradually rises again as one gets older and is still without a permanent mate.

For the second factor, the length of one's current relationship, we assume that one's willingness to commit (i.e., settle on one individual — i.e., marry — and no longer explore mate space for a potential mate) after a certain number of dates with the same individual is not the same at 20-25 as it is at a later age. Further, we assume that there is a difference in this regard between men and women, because of the problem for women's "ticking biological clock" that prevents them from conceiving children after a certain age. Women's fertility begins to drop in her late 20's, and by 40, the chance of getting pregnant is less than 10 percent (Dunson, Colombo & Baird, 2002), and, as a consequence, it is reasonable to assume that a less selective mate-choice strategy would be adopted by females from age 30 onwards. It is known (Pawlowski & Dunbar, 1999), for example, that women make increased efforts (that include age-deception) to meet men after age 35. Consequently, females in our model are most willing to commit quickly to marriage at around age 30, more so than at, say, 20 or in their menopausal and post-menopausal years (i.e., 45 and over). For men, with no biological clock to worry about, there is no peak fall-off at around 30. The Temperature graph in Figure 3 shows how these two variables combine for males. (For females, the decrease in Temperature due to the Number of Dates is steepest at around age 30.)

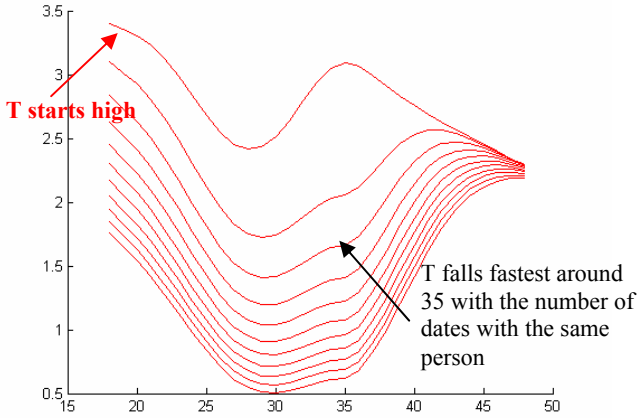

Figure 3. Female's Temperature as a function of Age and Number of Dates with the same male. Successively lines indicate number of dates. The Male temperature function is similar without the rise in temperature at 35.

Results

The goal of the present model is to explain how population-level empirical data can arise from a series of simple, psychologically plausible, stochastic choice mechanisms, coupled with evolving representations. To test KAMA, we drew on empirical data from Todd, et al. (2005), which they derived from data from the Eurostat, New Cronos database. We have followed Todd et al. (2005) in using a statistic called the *hazard-rate* to measure marriage rates for each age for during a given year. Marriage hazard-rate is calculated as follows. For a particular year, the marriage hazard-rate for a given age is the proportion of people of that age who married that year.

Overall first-marriage hazard-rates

We plotted a combined male-female hazard-rate functions for Norwegians in 1978. We created this curve by averaging the curves for Norwegian men and women from 1978. Figure 4 compares KAMA's results (averaged over 20 runs of the program) to this data. Clearly, the output of the simulation is a close match to the empirical data.

We compared the above empirical data to data produced by three parameter settings of a recent model by Todd et al.

(2005) that made it most closely resemble our own model. The results are shown in Figure 4b (all graphs drawn to the same scale, which was not the case in Todd et al., 2005). The dotted curve once again represents the empirical data from Norway 1978.

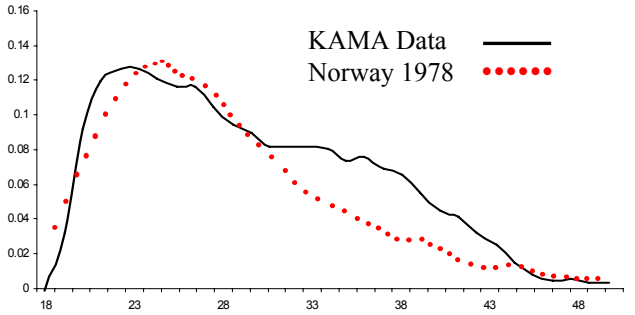

Figure 4a. Overall marriage hazard rates for Norway in 1978 and KAMA's output.

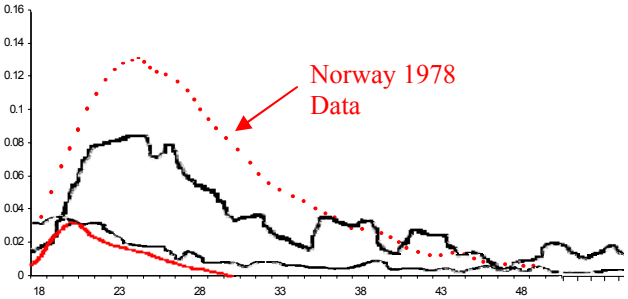

Figure 4b Marriage hazard rate comparison for Norway data (dotted red curve) and three different settings of Todd et al.'s model (2005, Figs. 4b, 5b, & 6).

Male-female marriage hazard-rate shift

We also analyzed these marriage hazard-rate data for 1978 separately by sex. A male-female shift can be seen in the empirical data. This is because between the ages of 18 and 28 significantly more women marry than men.

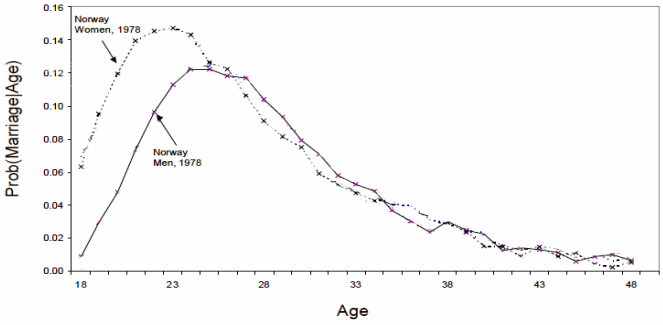

Figure 5. Initial leftward shift of the hazard-rate curve for women as a result of an approximately 2 year difference in age with their husbands.

KAMA achieved the same leftward and upward shift of the hazard-rate curve for women that is observed in the empirical data (Figure 6a).

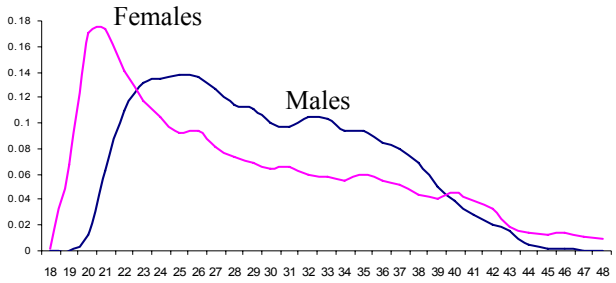

Figure 6a. Marriage hazard-rate curves for men and women produced by KAMA. Males marry on average 1.3 years later than females in the model.

The Effect of the Males-Ask/Females Decide Strategy on First-Marriage Hazard-Rates

Somewhat surprisingly, the model indicated that, even if the temperature curves for males and females were identical and, in addition, the preference-profiles for men and women were also identical, the strategy of Males-Ask/Females-Decide will, alone, engender a male-female hazard-rate shift, with males marrying later (Fig. 6b).

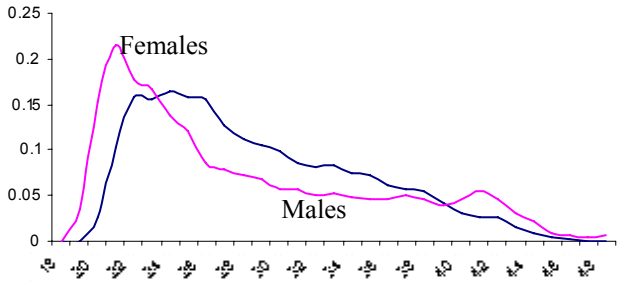

Figure 6b. Marriage hazard-rate curves for males and females with no difference in preference profiles or temperature curves.. The difference in average marrying age is approximately 0.5 years.

This is due to the fact that as each new 18-year-old women enters the population, she can be asked out by men whose ages range from ages 18 to 48. Among these men, there is a relatively high probability that she will find a compatible mate quickly and, if this happens, that mate will, more than likely, be older than she is.

Effect of Decreased Pressure to Marry

The social acceptability of the cohabitation of unmarried couples has grown since around the middle of the 1970's. As a consequence, living together without being married became a considerably more common practice, meaning an overall decrease in the marriage-threshold temperature. Individuals living together are still in the mating pool, leading to a flattening of the hazard-rate curve (Figure 7).

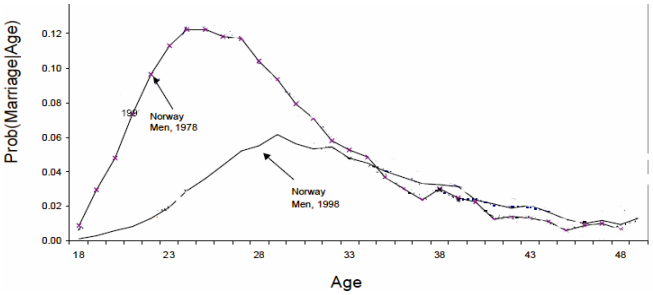

Figure 7. The increased social acceptability of unmarried cohabitation flattens of the marriage hazard-rate curve.

Decreasing the marriage-threshold temperature in our model does, indeed, produce the expected flattening of the first-marriage hazard-rate curve.

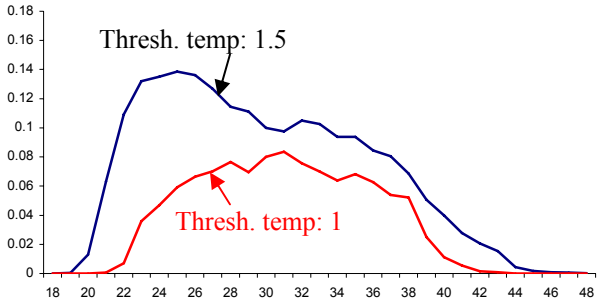

Figure 8. By modifying the marriage-threshold temperature, KAMA qualitatively matches the Norway 1978-1998 shift in marriage hazard-rates.

Conclusions

In this paper we have presented a mate choice model that incorporates a number of novel representational features and stochastic, temperature-driven individual decision-making mechanisms. We have replaced the notion that each individual has an intrinsic single mate-value with a "beauty in the eye of the beholder" principle. This means each individual has a set of preference weights corresponding to the descriptive characteristics of members of the opposite sex. In this way, the same individual will have a different mate-value depending on who is observing him or her. Further, individuals do not gain access to information about potential mates all at once, as in other models, but, rather, gradually, over the course of numerous contacts of various duration. Crucially, we have incorporated "computational temperature", inversely related to the variable called "mate choosiness" in the literature, that controls the focus of decision-making. High temperatures give decision-making a more random character; low temperatures produce more focused, deterministic decision-making.

The modest and preliminary results presented in this paper seem to show that a model constructed with individual-level mechanisms similar to those described here is capable of accurately reproducing empirical population-level marriage-rate data. We believe that the underlying structure of this model will allow relatively straightforward development of more sophisticated versions that will allow it to explore a much wider range of questions, including those involving changing selection strategies, as well as geographical and sociological constraints on the pool of potential mates.

Acknowledgments

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