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Uncertain Paternity, Mating Market Failure, and the Institution of Marriage

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UNCERTAIN PATERNITY, MATING MARKET FAILURE, AND THE INSTITUTION OF MARRIAGE*

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This paper provides a first microeconomic foundation for the institution of marriage. Based on a model of reproduction, mating, and parental investment in children, we argue that marriage serves the purpose of attenuating the risk of mating market failure that arises from incomplete information on individual paternity. Raising the costs of mating to individuals, marriage circumscribes female infidelity and mate poaching among men, which reduces average levels of paternal uncertainty in society. A direct gain in male utility, the latter induces men to invest more in their putative offspring, a fact that benefits women because of the public good nature of children. Able to realize Pareto improvements, marriage as an institution is hence explained as the result of a societal consensus on the need to organize and structure mating behavior and reproduction in society for the benefit of paternal certainty and biparental investment in offspring.
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1. Introduction

Marriage ranks among the oldest social institutions. Endorsed by religions, laws, and social norms throughout human history, it is a permanent fixture in virtually all cultures and of pivotal importance for the organization and structuring of mating markets. In light of this ubiquity and centrality in societies, it is little surprising that marriage has caught the growing interest of economic enquiry. Starting with Gary Becker's seminal work on the economics of marriage in the early 1970s (see Becker, 1973/1974), a truly extensive literature on marriage has developed over the last thirty years that has greatly enriched our knowledge of the family as an economic unit and added to our understanding of marriage patterns in societies. Despite the numerous advances made, however, a major gap remains in the economics literature on marriage. Disregarding the institutional nature of conjugal unions, economic theories of marriage have failed to explain the general purpose and regulatory function of marital arrangements in societies. Addressing this gap, this paper contributes to the economics literature on marriage by providing a first microeconomic foundation for the institution of marriage. We argue that marriage in society serves the purpose of mitigating risks of mating market failure that arise from spillover effects of promiscuous mating under incomplete information on individual paternity.

Economic theories of marriage in the Beckerian tradition have focused on various benefits to individuals from joining their production and consumption to explain the existence of conjugal unions. Potential sources of gain include the ability to exploit economies of scale or comparative advantage through specialization (Becker, 1985), risk sharing (Kotlikoff and Spivak, 1981, Hess, 2004), the production and consumption of household public goods including own offspring (Becker 1965; Pollack and Wachter, 1975; Lundberg and Pollak, 1993/1994), or the provision of credit when capital markets are imperfect (Cox, 1987/1990).[1] None of these gains, however, is confined to individuals in conjugal unions (Weiss, 1997). The same shortcoming applies also to other benefits that have been associated with marriage in the literature, such as the ability of co-residing couples to mutually monitor each other's parenting effort, a theme emphasized in the works of Willis (1999) and Weiss and Willis (1985, 1993), or the opportunity to economize on transaction costs within long-term relationships (see, for example, Pollak, 1985). Most economic theories of marriage in fact do not provide a definition of marriage that is distinct from other forms of interpersonal unions, such as nonmarital cohabitation.[2] Legal aspects of marriage are considered in only a strand of the economics literature. The latter includes theories which model marriage as a contract between spouses that protects them and their relationship-specific investments in case of breakup (see, for example, Landes, 1978; Pollack, 1985), or that transfers

[1]For surveys of theories of marriage, see, for example, the chapter by Weiss (1997) in the Handbook of Population and Family Economics, the monograph by Becker (1991), or the recent book by Grossbard-Shechtman (2003).

[2]This lack of differentiation between formal and informal unions has characterized the economics literature on marriage from its very beginning. As noted by Gary Becker's in the introduction of his seminal paper on the economics of marriage, for individuals "'marriage' simply means that they share the same household" (Becker, 1973, p. 815).

custodial rights from women to men (Edlund and Korn, 2002). These accounts are, however, still decidedly partial equilibrium in their treatment of marriage, as none of the features of marriage considered is in any way accounted for, but simply assumed. As other economic approaches to marriage, they furthermore treat marriage as an entirely private undertaking that concerns but those individuals who join a particular conjugal union. These shortcomings exemplify a general, and indeed significant gap in the economics literature on marriage, i.e. the lack of a microeconomic foundation for the institution of marriage that can explain why societies throughout history and across the world have endorsed marriage as the preferred and often only acceptable form of union between the two sexes and subjected it to various forms of social and legal sanctions.

Our paper contributes to the economics literature on marriage by providing a first such microeconomic foundation for the institution of marriage. To explain the origin and purpose of marital arrangements, we integrate economic theories of marriage and fertility in a model of reproduction, mating, and parental investment in children that takes explicit account of two fundamental asymmetries between women and men: asymmetry in offspring recognition and asymmetry in reproductive capacity. Our analysis shows that these asymmetries have a strong bearing on the respective reproductive strategies pursued by the two sexes, with major implications for mating market outcomes and efficiency. In the absence of regulation, they lead to excess mating and suboptimal levels of parental investment, that is to individual welfare losses. Underlying this market failure is incomplete information on individual paternity. The latter gives rise to externalities if promiscuous mating is unconstrained, that is cuckoldry and the concomitant risk for men to misattribute parental investment to offspring that is not their own. We show that an institutional arrangement that restrains promiscuity by raising its costs to individuals can realize Pareto improvements vis-à-vis this situation. For the less women and men engage in extra-pair mating, the more certain, on average, is individual paternity. A direct gain in utility for men, greater paternity confidence induces larger male parental investment in children, which benefits women because of the public good nature of child quality. Both sexes, as a consequence, have a fundamental interest in reducing average levels of paternity uncertainty in society. In our analysis, the institution of marriage is explained as the result of this shared interest among individuals to circumscribe promiscuity for the benefit of paternal certainty and biparental investment in offspring. Defining rules of courtship and norms of partnership formation and breakup that govern the kind and the scope of acceptable mating behavior in societies, marital arrangements largely determine the costs of mating to individuals. These include implicit costs for activities such as nonmarital sex, adultery, or out-of-wedlock childbearing. Organizing and structuring more than any other institution the operation of the mating market and reproduction in society, marital arrangements help to mitigate the risk of mating market failure that arises from female infidelity and mate poaching among men under incomplete information on individual paternity. Not differentiating between marital and nonmarital unions, economic theories of marriage have failed to explain this intimate relationship between marriage and reproduction. Although economists generally acknowledge the importance of childbearing for individual marriage decisions, most theories of marriage even "do not explicitly incorporate fertility decisions into the analysis" (Willis, 1999, p. S36). Other gains from marriage identified in the literature, however, cannot account for the traditionally intersexual nature of conjugal unions. For none of them accrues any less to groups of individuals of the same sex.

As misattributed fatherhood and mating market failure are universal risks faced by societies, our foundation of the institution of marriage is capable and general enough to account for the cross-cultural ubiquity and long history of marital arrangements.[3] Providing a rationale for the traditional status of marriage as the primary place for the bearing and rearing of children in societies, it can explain the generally inter-sexual nature of conjugal unions. It can also explain the ubiquitous endorsement and social sanctioning of fidelity between spouses, an intrinsic feature of marital arrangements hitherto altogether disregarded in the economics literature. Concerns about misattributed paternity can indeed account for numerous features of conjugal unions and marriage regimes, such as the rareness of polyandry across societies, the widespread importance attached to premarital female chastity, or the traditional status of unwed mothers as the sole legal custodian of their nonmarital offspring.

The importance of misattributed fatherhood for individual and group behavior has been intensively researched only outside economics, among others, in evolutionary biology, sociology, psychology, and anthropology (see Section 2 for more details), as economists have traditionally paid little attention to the biological basis of economic behavior. A recent series of papers, however, suggests that this situation may be slowly changing and that important advances can be made in our understanding of economic phenomena and human behavior more generally by broadening the scope of traditional economic enquiry.[4]

There are growing signs for a demise of marriage, however, at least in industrialized countries. Once a virtual precondition for childbearing, marriage appears to be increasigly decoupled from the bearing and rearing of offspring, as evinced by the growth in out-of-wedlock childbearing, rising rates of divorce, and declining marriage rates. A number of legal, technological, economic, and societal changes may account for this demise of marriage, including the introduction of unilateral divorce laws, improvements in household technology, the expansion of the welfare state, and increases in the female command of economic resources. While an analysis of the underlying causes of these changes is beyond the scope of this paper, our theoretical model is shown to provide a suitable framework for the study of their respective effects on the attractiveness and effectiveness of marital arrangements in societies.

[3]The ancient Greek philosopher Aristotle noted as early as 350 B.C.E. that one of the reasons why mothers seem to love their children more than fathers is the fact that they know better that the children are indeed their own (Nicomachean Ethics, Book 9, Chapter 7). General concern about cuckoldry has also found vivid expression in popular proverbs such as "mama's baby, papa's maybe", the modern English equivalent to the ancient Roman dictum "mater certissima, pater semper incertus" (mother is certain, father always uncertain).

[4]See, for example, the work by Cox (2003) on intervivos gifts and aspects of paternity uncertainty, Willis (1999) on out-of-wedlock childbearing, Edlund (1999) on preferences for sons versus daughters, Bergstrom (1996) on various aspects of families, or Robson (2001) on the biological basis of economic behavior more generally.

The paper is structured as follows. Section 2 surveys arguments for why the two sex differences considered in the analysis are important determinants of the respective mating market behavior of women and men. It also reviews the empirical literature, mostly from disciplines other than economics, on the importance of paternity and paternity confidence for the reproductive behavior of individuals and for the existence of various societal arrangements that regulate the mating, marriage, and parenting behavior of the two sexes. Section 3 develops and discusses the basic model. Section 4 characterizes the optimal female and male strategies and explains how these lead to mating market failure. Using a flexible parameterization, the underlying mechanisms of our model are illustrated graphically in Section 5. Based on the analytical framework developed and the results obtained, Section 6 provides a microeconomic foundation for the institution of marriage, analyses aspects of monogamous, polygynous, and polyandrous marriage regimes, and explores various legal, technological, economic, and societal trend changes in their effects on marriage patterns and parental investment levels. Section 7 summarizes the main findings and concludes.

2. Background

Outside economics, in evolutionary biology, sociology, anthropology, and psychology, sex differences have long been recognized as important determinants of both individual and group behavior. Asymmetries in offspring recognition and in reproductive capacity between women and men constitute two prominent examples of such differences. Both asymmetries arise from the human mode of reproduction and entail different constraints, risks, and incentives for the two sexes that significantly influence their respective reproductive strategies.

Because of internal fertilization and life birth, women but not men can identify their progeny with certainty. Men alone, therefore, are susceptible to the risk of cuckoldry. Misattributed fatherhood constitutes a major threat to the reproductive success of men and entails significant economic costs in terms of both time and resources expended for parenting. Internal fertilization and gestation, as well as a shorter female than male life-time span of fertility, furthermore significantly constrain the reproductive capacity of women relative to that of men. For men more than women, as a consequence, reproduction is limited by access to fertile mating partners. Both asymmetries are suggested in the literature to exert a qualitatively similar influence on the respective mating behavior of women and men and on the amount of parental investment each sex is willing to devote to offspring, i.e. the respective reproductive strategies pursued by the two sexes. In their strive for reproductive success, a function of both the quantity and the quality of own children, men are argued to maximize offspring quantity rather than quality, with the reverse holding true for women (Trivers, 1972; Symons, 1979).[5] Men more than women are hence

[5] A review of the literature on the trade-off between the quantity and quality of own offspring for the reproductive success of individuals, known as K-strategies and r-strategies in the biological literature, is provided in Hill and Kaplan (1999). See also Kaplan and Lancaster (2003).

predicted to aspire to multiple partners and women to contribute more than men to the rearing of children.[6] Male competition for females, a characteristic feature of the human mating system noted already by Charles Darwin in his work on the descent of man (Darwin, 1871), raises the individual odds of misattributed fatherhood when mate poaching among men is common, and hence adversely affects male parenting levels. For the more uncertain is paternity, the less willing are men on average to invest in their alleged progeny (e.g. Alexander, 1974), and the more attractive is promiscuity as a means to increase their expected number of offspring (Bateman, 1948) and to diversify potential risks of cuckoldry. As motherhood, in contrast, is certain and female reproductive capacity limited, women do not have these incentives to engage in promiscuity. They have other motives, however, in particular, the prospects of acquiring additional (yet misplaced) parental investment from other males (Stacey, 1982). For women, therefore, extra-pair mating essentially remains part of a quality-maximizing reproductive strategy.[7]

Given the obvious difficulties involved in gathering data on perceived paternity, there have been only few direct tests of its effects on male parenting and mating behavior.[8] One of the rare empirical studies addressing the issue is the recent work by Anderson et al. (2007), which is based on self-reported retrospective data on the marital, reproductive, and parenting histories of men in Albuquerque, New Mexico. In the survey, carried out between 1990 and 1993, respondents were asked to indicate their degree of paternity confidence for each pregnancy attributed to them. Using Cox proportional hazard and ordered logistic regressions, the study finds low paternity confidence to increase the likelihood of men to divorce their wives, to lower the time they spend with their putative children, and to reduce their involvement with the educational progress of their alleged progeny. Drawing from data of a telephone survey of men in Knox County, Tennessee, the study by Fox and Bruce (2001) also finds evidence of a positive relationship between paternity confidence and measures of paternal care. Their findings, however, appear sensitive to the particular measure of fathering employed. The study furthermore lacks a detailed description of how the measure of paternity confidence employed in the analysis has been constructed from the sampled survey information.

A wealth of empirical studies on related topics, however, provides ample evidence for the importance of paternity and paternity confidence for male mating and parenting behavior, as well as for societal arrangements that govern mating markets in societies. Corroborative pieces of evidence include higher mate guarding among men (e.g. Buss, 2002), male jealousy and the sexual double standard (e.g. Daly et al., 1982; Shackelford et al., 2002), and the greater valuation

[6] Consistent with these reproductive strategies, significant sex differences have been observed across cultures also in mate preference. Men more than women tend to value signals of reprodutive capacity or fertility in potential mates, such as features of physical appearance that are associated with youth and health. Women, in contrast, appear to put greater emphasis on attributes like status or earnings capacity, i.e. cues to the ability of potential mates to support them and their offspring (see, for example, Buss, 1989).

[7] For a thorough treatment of the importance of female infidelity and paternal uncertainty for human mating strategies, see the recent book by Shackelford and Platek (2006).

[8] Relatively little is also known on rates of actual paternity, for major difficulties are similarily encountered in the collection of reliable data on biological fatherhood (see Anderson, 2006 for a cross-county review of the available evidence).

among men of physical resemblance to children as an indirect means to ascertain their paternity (e.g. Daly and Wilson, 1982; Platek et al., 2002/2003; Volk and Quinsey, 2002). Further evidence pertains to inferior investment in offspring by patrilineal than matrilineal kin (e.g. Gaulin et al., 1997), greater investment of brothers into the children of their sisters if own paternity is highly uncertain (Alexander, 1979), the dependence of rules of inheritance of a man's property across societies on paternal confidence (Gaulin and Schlegel, 1980; Hartung, 1985), and the relationship between average levels of paternal uncertainty and rules governing consanguineous marriages or inbreeding in societies (Greene, 1978). Moreover, the once exclusive definition of adultery with respect to the marital status of women in many societies (e.g. Hadjiyannakis, 1969; Bullough, 1976), the general importance attached to female premarital chastity (e.g. Buss, 1989), the commonness of polygyny but rareness of polyandry (Murdock, 1967), and the universality of the paternity presumption in marital arrangements across societies (Edlund, 2005) all bear witness to the predominantly reproductive nature of marriage as an institution and the pivotal role of paternal uncertainty for human mating markets. Finally, there is ample evidence that the presence of both biological parents matters a great deal for the well-being of children. Stepchildren, in particular, have been shown to suffer in a number of ways (e.g. Case et al., 1999; Daly and Wilson, 1985; Wilson and Daly, 1987).

3. The Model

This section develops a model of reproduction, mating behavior, and parental investment in children under asymmetries in offspring recognition and reproductive capacity between the two sexes. The model is kept deliberately parsimonious in that no more assumptions are made than needed to illustrate our theory of the institution of marriage as a societal response to mating market failure arising from the aforementioned two asymmetries. We begin our description of the model in Section 3.1 with the specification of the preferences, endowments, and reproductive technologies of women and men. Child quality as the result of parental investment is modeled in Section 3.2. Completing the discussion of the model, Section 3.3 defines equilibrium in the aggregate mating market.

3.1. Preferences, Endowments, and Reproductive Technologies

Consider a society populated by a large number of single-period lived fertile women and men with equal preferences, where individuals of the same sex are homogeneous in terms of their respective endowments and reproductive technologies. Individuals are rational and can spend their economic resources on two competing uses: non-reproductive consumption and reproduction. Resources devoted to non-reproductive consumption may hence be viewed as the opportunity cost of resources spent on reproduction. Resources spent on reproduction consist of expenditures for mating and parenting. Furthermore, women and men are assumed to mate for reproductive purposes only.

We first consider females. Women are endowed with wealth, time, and other economic resources, which are summarized by variable $Y_♀$. They derive separable utility $W_♀$ from non-reproductive consumption $C_♀$ and reproductive success, which is a function of both the (discrete) number $K_♀$ and the (continuous) quality measure Q of own biological offspring:

$$W_♀ \left(C_♀, K_♀, Q\right) = U \left(C_♀\right) + V \left(K_♀, Q\right). \tag{1}$$

To account for physiological constraints in female fertility, the reproductive capacity of women is assumed to be bounded by an upper limit. Following Willis (1999), we normalize this upper limit to one, i.e. $K_♀ \in \{0, 1\}$. As women are homogeneous, this assumption implies that the average number of children per woman is also either 0 or 1. The functions U and V are assumed to be twice differentiable in their respective arguments. U is increasing at a diminishing rate, i.e. $U'' < 0 < U'$, and V has the following properties:[9]

$$V(0,0) = V(0,Q) = V(K,0) = 0 \quad \text{and} \quad V_{KK}, V_{QQ} < 0 < V_K, V_Q, V_{KQ}; \quad \forall\, K, Q > 0, \tag{2}$$

i.e. both mating and parental investment into child quality Q are required for female reproductive success. Mating is costly for both sexes. The respective cost of an additional partner for each sex is determined on the aggregate mating market and treated as exogenously given by individuals. For a woman, mating a male individual is assumed to require marginal cost $s_♀$ relative to female non-reproductive consumption. Child quality too has its price. Denoting by $a_♀$ the resources at which an additional female contribution $Q_♀$ to total child quality Q can be obtained, each woman faces the following budget constraint:

$$Y_♀ = C_♀ + s_♀ N_♀ + a_♀ K_♀ Q_♀, \tag{3}$$

where $N_♀$ is the number of male partners a female has. Choosing $N_♀$ and her investment in child quality $Q_♀$, a woman maximizes her utility (1) subject to her budget constraint (3).

We next turn to men. Like women, men are assumed to have identical preferences and endowments $Y_♂$ and derive utility from non-reproductive consumption and reproductive success. Unlike women, however, men are restricted in their reproductive capacity only by access to fertile members of the opposite sex (Bateman, 1948). They may therefore father more than one child by mating several women. Moreover, unlike women, men do not recognize their offspring. Being rational, however, men can infer the total number of male mates $N_♀$ each of their female partners has in equilibrium. For a child born by one of his female partners, a man's probability of fatherhood δ is therefore inversely related to the number of male partners $N_♀$ the female has

[9] The assumption that V is twice differentiable with respect to discrete K can be relaxed, as long as V is monotonously increasing and strictly concave in K.

mated, i.e.:

$$\delta = N_{♀}^{-1} \qquad \Leftrightarrow \qquad 1-\delta = 1 - N_{♀}^{-1}, \tag{4}$$

where the second equation gives the degree of paternal uncertainty experienced by the man. If δ is equal to one, i.e. women are monogamous, a man can be absolutely certain about his biological parenthood. If women are promiscuous, however, paternity is uncertain. In this case, the actual but unknown number of own offspring $K_{♂}$ of a man that mates $N_{♂}$ females can be any integer up to and including $N_{♂}$, i.e. $K_{♂} \in \{0, .., N_{♂}\}$. Given $N_{♂}$ and δ, the probability of a man to father exactly $K_{♂}$ children therefore follows the binomial distribution with parameters $N_{♂}$ and δ:

$$\mathrm{Prob}\left(K_{♂}; N_{♂}, \delta\right) = \binom{N_{♂}}{K_{♂}} (1-\delta)^{N_{♂}-K_{♂}}\, \delta^{K_{♂}}. \tag{5}$$

Denoting by E the expectations operator under the above binomial distribution, the expected number of offspring $K_{♂}^{e}$ of a man with $N_{♂}$ female partners is hence given by:

$$K_{♂}^{e} \equiv E\left[K_{♂}\right] = \delta N_{♂}. \tag{6}$$

Because of asymmetry in offspring recognition, therefore, men unlike women only maximize their expected utility. Denoting the latter by $W_{♂}$, the objective function of a man reads:

$$W_{♂}\left(C_{♂}, K_{♂}, Q\right) = U\left(C_{♂}\right) + E\left[V\left(K_{♂}, Q\right)\right]. \tag{7}$$

Mating a female individual requires marginal cost $s_{♂}$ in terms of male non-reproductive consumption. Denoting further by $a_{♂}$ the resources at which a marginal male contribution to child quality can be obtained, a man faces the following budget constraint:

$$Y_{♂} = C_{♂} + s_{♂} N_{♂} + a_{♂} N_{♂} q_{♂}. \tag{8}$$

By choosing the number of his female partners $N_{♂}$ and the level of his quality investment per child $q_{♂}$, a man maximizes expected utility (7) subject to his budget constraint (8).

3.2. Parental Investment and Child Quality

Child quality Q is determined by female and male investments in children. As motherhood is certain, the biological mother of a child is the only female that contributes to its quality. Among men, however, all partners of a mother qualify as potential fathers. As a consequence, all male partners of a mother will invest in the quality of her child. Total child quality Q is therefore composed of the parental investment of the biological mother ($Q_{♀}$) and the sum of the individual contributions ($q_{♂}$) of her male partners. Note that as Q enters into the utility functions of both women and men (see equations (1) and (7) above), maternal investment in children affects male utility and vice versa. As in Weiss and Willis (1985), therefore, child quality has the character of a public good. Moreover, if $N_♀ > 1$, the true but unknown biological father benefits from contributions of his male competitors to the quality of his child.

Child quality Q is assumed to be the result of a constant elasticity of substitution aggregation procedure with maternal investment in child quality $Q_♀$ and the total sum of male contributions of potential fathers $Q_♂$ as arguments:

$$Q = \left[\alpha Q_♀^{\frac{\eta-1}{\eta}} + (1-\alpha) Q_♂^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}, \tag{9}$$

where parameter α weighs the respective contributions of the two sexes, and η measures the degree of substitutability between female and male contributions to the quality of a child. This very general specification permits to study a whole spectrum of possible aggregation procedures, ranging from perfect complementarity ($\eta \to 0$) to perfect substitutability ($\eta \to \infty$), where $\eta = 1$ corresponds to a Cobb-Douglas specification. While the actual degree of substitutability between female and male contributions to child quality is difficult if not impossible to determine in practice, it seems fair to say that both extrema, i.e. $\eta \to 0$ and $\eta \to \infty$, are rather unlikely.

In equilibrium, symmetry among male individuals implies that the quality investment $q_♂^{(i)}$ of a potential father i in a certain child is equal to the quality investment $q_♂$ of a representative man in one of his potential offspring. Total male contributions to the quality of a particular child are therefore given by the product of its mother's number of mating partners $N_♀$ and the contribution $q_♂$ of a representative man:

$$Q_♂ = \sum_{i=1}^{N_♀} q_♂^{(i)} = N_♀ q_♂. \tag{10}$$

3.3. Mating Market

The individual reproductive strategies of women and men have to be consistent in equilibrium with a situation of mating market clearing. Let $P_♀$ ($P_♂$) denote the mass of the female (male) population in society. The mating market clears when the number of male partners per women $N_♀$ divided by the number of female partners per men $N_♂$ is equal to sex ratio ϕ, i.e.:

$$\frac{N_♀}{N_♂} = \frac{P_♂}{P_♀} \equiv \phi. \tag{11}$$

Per match, total mating costs s accrue, which reflect all costs associated with reproductive mating, including the monetized values of social, legal, and religious conventions. A detailed discussion of the determination of s is provided in Section 6.1. For the moment, we assume s to be exogenous, a deadweight loss, and shared between the two sexes:

$$s = s_♀ + s_♂. \tag{12}$$

In equilibrium, $s_♀$ and $s_♂$ are determined by market forces, i.e. by the respective relative valuations (demands for) and supplies of women and men for another partner of the opposite sex. Mating market clearing is hence achieved through the price mechanism. Like an invisible hand or a central dating agency, it sets, for a given value of s, the respective mating costs of women and men to levels that are consistent with a situation of mating market clearing.

In reality, of course, societies rarely set s. Rather they try to govern directly the respective costs of mating to men and in particular to women. These costs assigned by society, however, need not coincide with the actual costs that women and men have to bear on the mating market. For market forces, i.e. the price mechanism, will entail some redistribution of these costs across the two sexes in the form of compensation or side payments, should the mating market fail to clear.[10] Our modeling assumption that s is set by society is therefore rather innocuous.

4. Analysis

According to our theory, the institution of marriage serves the purpose of attenuating the risk of mating market failure that arises from incomplete information on individual paternity. In this section, we solve our model for the optimal individual reproductive strategies of the two sexes, and show that these do indeed lead to mating market failure. For individuals, behaving non-cooperatively, fail to internalize the social costs of promiscuous behavior, which consist of resources expended in excess of the minimum required for reproduction and direct utility losses for men because of uncertain paternity.

We proceed as follows. Sections 4.1 and 4.2 derive and discuss the respective optimal strategies of women and men, and explore the influences on these strategies of various parameters in the model. Section 4.3 shows how these individually optimal strategies lead to mating market failure.

4.1. Limited Reproductive Capacity and Optimal Female Strategies

Suppose agents are better off if they participate in mating, i.e. they can attain a higher level of utility than their reservation utility $U(Y)$, $Y \in \{Y_♀, Y_♂\}$. In this case, the average number of births per woman is equal to one (see Section 3.1), and the female optimization problem can be restated as follows:

$$\left\{Q_♀, N_♀\right\} = \arg\max \left\{U\left(Y_♀ - s_♀ N_♀ - a_♀ Q_♀\right) + V\left(1, Q\right)\right\}. \tag{13}$$

Mating an additional man increases the utility of a woman as long as the following inequality holds:

$$V(1, Q^{N_♀+1}) - V(1, Q^{N_♀}) \geq U\big(C_♀^{N_♀}\big) - U\big(C_♀^{N_♀+1}\big), \tag{14}$$

[10] Taxation of but one sex is in fact ruled out by our market clearing condition (11).

where $C_{♀}^{N_{♀}}$ is the non-reproductive consumption of a woman with $N_{♀}$ male partners, and $Q^{N_{♀}}$ denotes the total quality of her child when $N_{♀}$ male partners invest in her offspring. The optimal number of male partners for a woman is therefore such that the loss in utility from reduced non-reproductive consumption is less than or equal to the increase in utility from higher child quality when mating an additional partner. The only benefit of promiscuity to a woman are therefore the individual contributions to child quality $q_{♂}$ of her male partners. Female mating costs per man $s_{♀}$, as a consequence, can be viewed as the marginal cost to a woman of securing an additional male contribution to the quality of her child, i.e. of pursuing such a quality-oriented reproductive strategy. An increase in $s_{♀}$ will hence lead to a decline in the optimal number of male partners per woman, unless men increase sufficiently their individual contributions to child quality.

Optimal female investment in child quality $Q_{♀}$, in turn, has to satisfy:

$$a_{♀} U'\left(C_{♀}\right) = \alpha \left(\frac{Q}{Q_{♀}}\right)^{\frac{1}{\eta}} V_Q\left(1, Q\right), \tag{15}$$

i.e. at the optimum a marginal female contribution to child quality has to equate the marginal loss in non-reproductive utility to the marginal increase in utility due to higher child quality. Note that for $Q < Q_{♀}$, which is equivalent to $Q_{♂} < Q_{♀}$, a reduced female dependence on male contributions, i.e. an increase in η, will lead to a reallocation of female resources from non-reproductive consumption to parenting.

These optimal strategies of a woman imply that her allocation of resources between mating and parenting is determined by just three factors: the ratio of female to male child quality contributions $Q_{♀}/Q_{♂}$, the measure of the relative contribution shares of the two sexes α, and the elasticity of substitution η between female and male contributions to the quality of a child. A greater female command of economic resources $Y_{♀}$, therefore, increases ceteris paribus both her reproductive and non-reproductive expenditures, but leaves her distribution of reproductive resources across mating and parenting unaltered. In equilibrium, a higher female demand for male partners will of course also entail a price effect, i.e. female and male shares in total mating costs adjust, so that the optimal behavior of both sexes will be affected too. A change in $a_{♀}$, in turn, gives rise not only to an income effect of the kind just described, but also to a substitution effect, as the relative prices of competing uses are changed. In particular, a fall in $a_{♀}$ will induce a reallocation of resources from non-reproductive consumption to reproduction.

4.2. Uncertain Paternity and Optimal Male Strategies

Treating the probability of biological fatherhood δ as exogenously given, a male individual chooses $N_{♂}$ and $q_{♂}$ to maximize his expected utility:

$$\{q_{♂}, N_{♂}\} = \arg\max \left\{U\left(Y_{♂} - s_{♂} N_{♂} - a_{♂} N_{♂} q_{♂}\right) + E\left[V\left(K_{♂}, Q\right)\right]\right\}. \tag{16}$$

An application of the law of iterated expectations shows that adding one additional partner to a given number of female partners $N_{\male}$ increases the expected utility of a man, as long as the following inequality holds:

$$\delta E\left[V(K_{\male}+1,Q)-V(K_{\male},Q)\right] \geq U(C_{\male}^{N_{\male}})-U(C_{\male}^{N_{\male}+1}), \tag{17}$$

where $C_{\male}^{N_{\male}}$ is the consumption expenditure of a man with $N_{\male}$ female partners. In other words, the expected increase in male utility derived from an additional reproductive success weighted by the probability of biological fatherhood (δ) has to equal or outweigh the loss in utility caused by reduced non-reproductive consumption when resources are transferred to the mating market. Promiscuity is therefore attractive to a man, because it increases his expected number of offspring. Male mating costs per female partner $s_{\male}$ can hence be interpreted as the marginal cost to a man of pursuing such a quantity-oriented reproductive strategy. An increase in $s_{\male}$, therefore, has to be accompanied for a man by a sufficient increase in his expected utility from own offspring to leave his optimal number of female partners unaltered.

The first order necessary condition for the optimal contribution to child quality of a man is given by:

$$a_{\male}N_{\male}U'\left(C_{\male}\right)=(1-\alpha)\left(\frac{Q}{Q_{\male}}\right)^{\frac{1}{\eta}}E[V_Q(K_{\male},Q)]. \tag{18}$$

The interpretation of (18) is analogous to the respective condition for females. Note that $N_{\male}$ appears on the left-hand side of equation (18) because a man invests in the children of all of his female partners. Note also that an increase in the number of male competitors $N_{\female}$ scales down the $Q/Q_{\male}$ ratio and reduces the expected marginal utility from child quality. Because of the latter, a man would lower his investment in child quality, which in turn reduces his marginal utility of non-reproductive consumption and increases his expected marginal utility of child quality. As long as $Q_{\male}<Q$, which is equivalent to $Q_{\male}<Q_{\female}$, a similar shift of male resources to non-reproductive consumption occurs for lower degrees of female dependence on male child quality contributions, i.e. for higher levels of η. As pointed out before, the true but unknown biological father of a child therefore benefits from the quality investments of other men.

The allocation of reproductive resources by men between mating and parenting is not only determined by $Q_{\female}/Q_{\male}$, α, and η, as in the case of females, but also by three other factors. These are the probability of fatherhood δ, the sex ratio ϕ, and the concavity of the function V with respect to the quantity and the quality of own offspring. The income effect induced by a greater male command of economic resources $Y_{\male}$ therefore deviates ceteris paribus from the one in the female case. In particular, men devote a larger share of (any additional) reproductive resources to mating than women, i.e. they pursue a reproductive strategy that emphasizes child quantity rather than quality. In equilibrium, of course, a higher demand among men for female partners would also result in a larger male share in total mating costs, so that female behavior is affected as well. Finally, and as for women, a fall in $a_{\male}$ has both an income and a substitution effect.

As the preceding discussion has shown, promiscuity is attractive to both sexes, albeit for different reasons. Men may increase their expected number of children through extra-pair mating, but women can gain only additional male contributions to the quality of their children. For women, therefore, promiscuity essentially remains part of a quality-maximizing strategy. This differential incentive structure for women and men is consistent with the earlier noted quality-quantity distinction in the reproductive strategies pursued by the two sexes.

4.3. Mating Market Failure

Promiscuous behavior, although optimal from an individual perspective, entails social welfare losses. Not only do mating expenditures exceed the social minimum required for reproduction, but extra-pair mating endangers male reproductive success by making individual paternity uncertain. Acting non-cooperatively, women and men fail to internalize these spillover effects when deciding on their respective optimal number of partners, which leads to excess mating and ultimately mating market failure.[11] Although the two sexes would benefit if all women were monogamous and men refrained from mate poaching, individually each woman and man has strong shirking incentives. The prospect of a woman to attract additional male quality contributions and the possibility of a man to increase his expected number of offspring through extra-pair mating prevent coordination. A general increase in the cost of mating, however, can mitigate this market failure. In other words, Pareto improvements can be achieved, if mating in excess of the minimum required for reproduction and hence average levels of paternal uncertainty are reduced. A graphical illustration of this line of argument is provided in the next section.

5. A Graphical Illustration

We use a very general parameterization of our model and change in the following to a continuous choice framework.[12] Separable utility of women and men is chosen to be isoelastic in non-reproductive expenditures and Cobb-Douglas in the quantity and quality of own children (see equations (1) and (7)):

$$U(C) = \gamma \frac{C^{1-\sigma} - 1}{1-\sigma} \qquad \text{and} \qquad V(K, Q) = (1-\gamma) K^{\kappa} Q^{\theta}, \tag{19}$$

where $\gamma, \kappa, \theta \in (0,1)$, and $\sigma > 0$. Parameter γ, a measure of the degree of parental altruism toward offspring, weights the two sources of utility.[13] Parameter σ is the absolute value of the elasticity of marginal utility with respect to the non-reproductive usage of endowments, and

[11] In other words, equilibrium allocations of resources will differ from the social optimum. A detailed discussion of the social optimum and of the cooperative reproductive strategies required for its attainment are provided in Appendix A.

[12] The continuous choice first order necessary conditions are provided in Appendix B.

[13] Parental altruism toward offspring is a special case of concern for biological relatives (Hamilton, 1964a/b).

parameters κ and θ determine the degree of concavity of utility with respect to the quantity and quality of own children. For our baseline specification, we normalize the endowments of both sexes to one and set parameters α, γ, κ, and θ to one half. Furthermore, we assume logarithmic preferences, Cobb-Douglas aggregation of parental contributions to child quality, and a balanced sex ratio ($\sigma = \eta = \phi = 1$). The qualitative influence of most parameters is very intuitive, with the exception of the degree of substitutability between female and male child quality contributions (η). Its role will therefore be studied in greater detail in Section 5.3. Later sections tie up with this discussion and vary also some of the other parameters (see Sections 6.2 and 6.3).

The following three subsections explore the effects of broad variations in the level of total mating costs s and per-unit child quality costs a on the equilibrium number of partners per individual and on the degree of paternal uncertainty experienced by men (Section 5.1), the levels and shares of female and male contributions to child quality and its overall level (Section 5.2), and the individual welfare of women and men (Section 5.3). For our line of argument, the effects of variations in total mating costs are of central importance. As we will see, increases in s lessen the mating market failure that arises from uncoordinated mating behavior under incomplete information on individual paternity.

5.1. Mating Costs, Number of Partners, and Paternal Uncertainty

The two diagrams of Figure 1 document how equilibrium female and male mating costs change in reaction to variations in overall mating costs s and in per-unit child quality costs $a = a_♀ = a_♂$, which are measured in percent of an individual's endowment. As can be seen, both $s_♀$ and $s_♂$ increase in s. Male mating costs, however, exceed female mating costs over the entire range of total mating costs considered in the diagrams. The latter finding reflects the generally greater valuation of promiscuity among men than women because of the different reproductive strategies pursued by the two sexes.

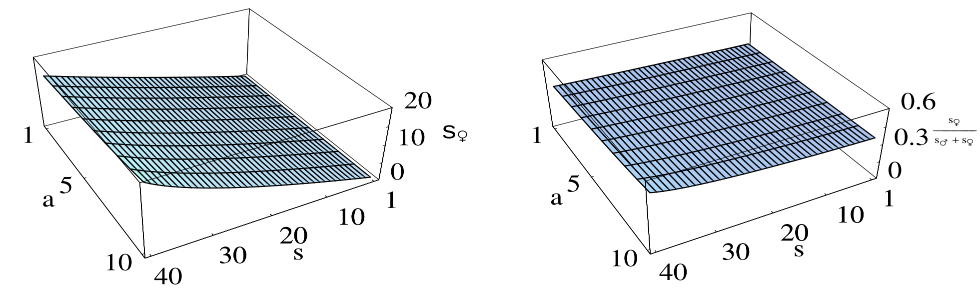


FIGURE 1: Market clearing female and male mating costs.
Left: $s_♀$ absolute. Right: $s_♀$ relative to total mating costs.

As shown in Figure 2, the equilibrium number of partners $N = N_♀ = N_♂$ per individual and, in consequence, paternal uncertainty $1 - \delta$ decline monotonically, as mating becomes more costly for both sexes. This inverse relation between mating costs and paternity uncertainty is of central importance to our foundation of marriage (see Section 6.1). For it implies that the very source of mating market failure can be easily attenuated in society by raising the costs of mating to individuals. Increases in the level of per-unit child quality costs also tend to reduce the number of partners, and hence the degree of paternal uncertainty experienced by men.

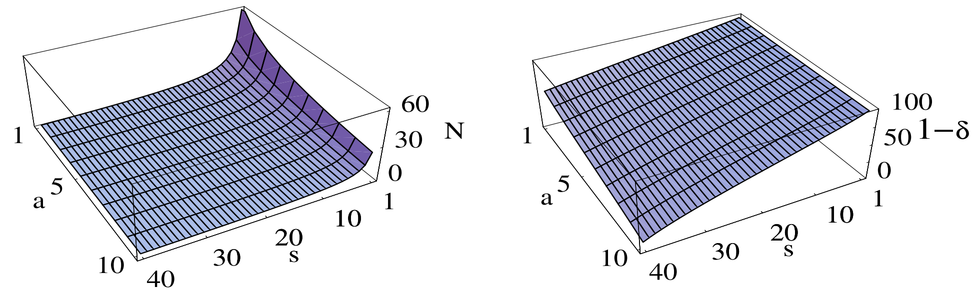


FIGURE 2: Equilibrium number of partners and implied paternal uncertainty.
Left: Number of partners N. Right: Paternal uncertainty $1-\delta$.

5.2. (Parental) Investment in Child Quality

An increase in total mating costs makes parental investment for a given child more attractive for both sexes (Figure 3). Mating expenditures of women and men in fact rise too. Measured by their expenditure share in total resources devoted to reproduction, however, child quality investments become relatively more important for both sexes. As paternity gets more certain when s increases, this effect is more pronounced for men.

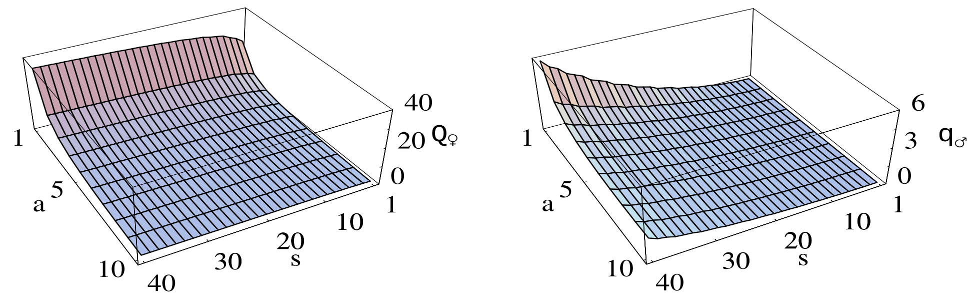


FIGURE 3: Female and individual male contributions to the quality of a child.
Left: Female contribution $Q_{♀}$. Right: Individual male contribution $q_{♂}$.

Whether total child quality Q rises or falls when mating costs increase depends on the relative rates at which the number of male contributors (partners) $N_{♀}$ to the quality of a child declines and the level of individual male contributions $q_{♂}$ rises, i.e. how total male contributions $Q_{♂}$ change (see equation (10)). As shown in the first diagram of Figure 4, total male contributions to child quality $Q_{♂}$ do increase when mating becomes more costly. As maternal investment in the quality of a child has been shown to increase as well in the level of mating costs, overall child quality Q unambiguously rises in s. A mother's share in total child quality, however, declines markedly as fewer male partners contribute more in sum to the quality of her child. As a consequence, both men (directly) and women (indirectly) benefit from lower levels of paternal uncertainty, which are attained by making promiscuous behavior more costly.

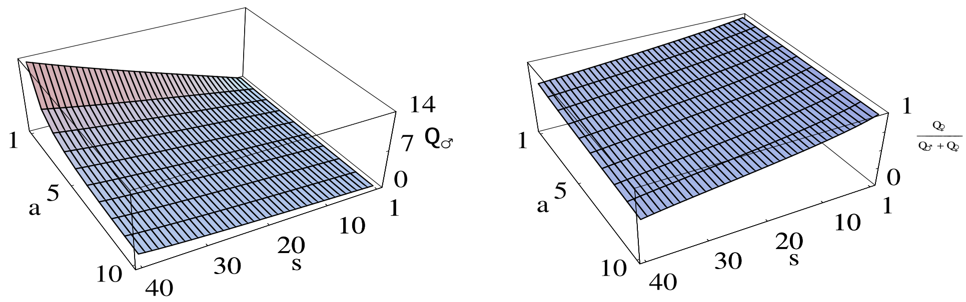


FIGURE 4: Total male contributions and female share in parental investment per child. Left: Total male contributions $Q_{♂}$. Right: $Q_{♀}$ relative to $Q_{♀} + Q_{♂}$.

5.3. Welfare

As we have seen, the equilibrium number of partners and the degree of paternal uncertainty decline in the level of mating costs, while overall child quality and the male share in total child investments rises. Men, therefore, benefit primarily from lower levels of paternal uncertainty when mating becomes more costly, and women profit from greater male contributions to child quality. We next explore how different levels of mating costs affect the utility of women and men. Figure 5 plots the welfare of women $W_{♀}$ and the expected welfare of men $W_{♂}$ for different mating costs s and child quality costs a. As is evident, for all values of a, the utility of women and the expected utility of men increase monotonically in the level of mating costs. Welfare in the economy, therefore, unambiguously rises if the deadweight costs of mating are increased, and promiscuity and paternal uncertainty decline. Reducing the risk of misattributed fatherhood in society is hence not only feasible, as shown in Section 5.1, but indeed desireable.

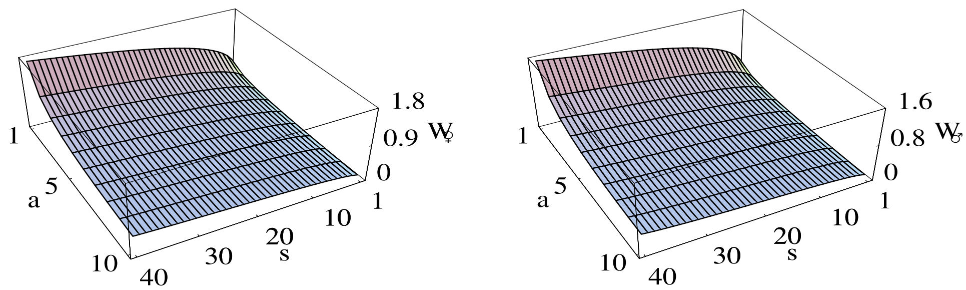
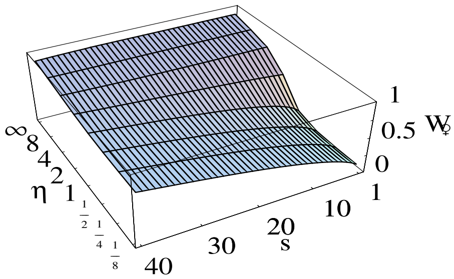


FIGURE 5: Welfare of women and expected welfare of men. Left: Female welfare $W_{♀}$. Right: Expected male welfare $W_{♂}$.

To check the robustness of this central result with respect to different degrees of substitutability between female and male contributions to child quality η, Figure 6 plots the utility of women and the expected utility of men for different levels of s and η, holding per-unit child quality costs constant. For low values of η, i.e. for low degrees of substitutability, the (expected) welfare of (men) women increases strictly in the level of mating costs s. For higher values of η, however, the respective curves become u-shaped, a change that sets in earlier for men. Welfare levels attained by both sexes at sufficiently high levels of mating costs nevertheless continue to exceed those at low levels of mating costs. Men and women are therefore always strictly better off at some high level of mating costs. A decrease in child quality costs a, in turn, raises the respective welfare of women and men for a given level of mating costs and compresses the u-shaped welfare curves such that a higher level of welfare than at baseline is attained by both sexes already at lower levels of mating costs.



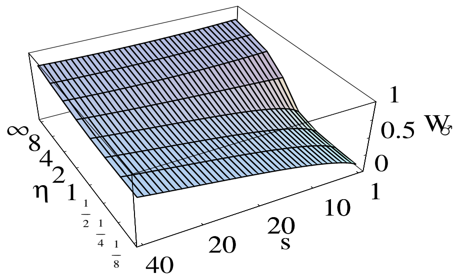


FIGURE 6: Welfare of women and expected welfare of men with respect to η.
Left: Female welfare $W_{♀}$. Right: Expected male welfare $W_{♂}$.

6. Marriage

In the analysis so far, mating costs have been treated in generic terms only and their level has been varied but exogenously. In Section 6.1, we explore the nature and the determination of mating costs in detail, arguing that their level in society is largely a function of the strictness of the particular marital arrangement in force. Section 6.2 discusses monogamous, polygynous, and polyandrous marriage regimes, explores their underlying determinants, and describes their common features as well as differences, showing that many a characteristic that is shared or peculiar to one regime can indeed be explained by the concern of men and society about paternal uncertainty in reproduction. Finally, Section 6.3 discusses a number of legal, economic, and technological trend changes that may have contributed to the decline of marriage observable in many countries over the last century.

6.1. The Institution of Marriage

In an archaic world, mating is rather inexpensive, being subject to little more than shoe-leather costs. In civilizations, however, mating costs tend to be much larger. Being determined and enforced by social, legal, and religious conventions, mating costs reflect rules of courtship and norms of partnership formation and breakup that govern the kind and the scope of acceptable mating behavior in societies. Once a virtual precondition for childbearing and for a long time the only tolerable form of union between the two sexes, marriage remains to the present day the single most important social institution in the mating market. Marital arrangements, viewed broadly, still determine directly or indirectly the costs to individuals, among others, of divorce, adultery, informal cohabitation, and out-of-wedlock childbearing. In short, the stricter are marital arrangements in societies, the more costly is promiscuous behavior to individuals, and the more circumscribed in consequence is mating.

In the context of our model, the stringency of marital arrangements is measured by the level of mating costs. As these are inversely related to the degree of paternal uncertainty, and welfare-enhancing if set to sufficiently high levels, women and men by consensus would favor the enactment and enforcement of marital arrangements. If prevalent social norms reflect majority preferences, then marriage as an institution can be explained as the result of this shared interest among individuals to reduce average levels of paternal uncertainty in society. This microeconomic foundation for the institution of marriage is capable of accounting not only for the universality and long history of this social institution. It can also explain the traditional role of marriage as the primary place for the bearing and rearing of children in societies, and hence the generally intersexual nature of marital unions. Furthermore, our foundation provides a convincing rationale for a feature of conjugal unions hitherto altogether disregarded by economic theories of marriage, i.e. the ubiquitous social endorsement and enforcement of fidelity between spouses.

Asymmetries in offspring recognition and in reproductive capacity between the two sexes are instrinsic features of the human mode of reproduction. Misattributed fatherhood and mating market failure are therefore ubiquitous risks faced by societies and in no way confined to particular cultures, times, economic systems, or regions of the world. Actual marriage regimes, no doubt, exihibit great diversity, as societies have responded differently to these risks, depending on the specific environmental, technological, and demographic circumstances encountered. In the next section, we explore this diversity in greater detail by analyzing its most prominent realizations (monogamy, polygyny, and polyandry) and the particular circumstances that may give rise to them.[14] The respective prevalences, common features, and idiosyncratic characteristics of these marriage regimes are shown to provide ample evidence for the ubiquitous importance of paternal uncertainty and limited female reproductive capacity for individual mating behavior and societal arrangements governing the mating market.

[14] We ignore group marriages, i.e. conjugal unions between several husbands and wives, as such arrangements have at no time been predominantly practiced in societies (see Table 1). A likely reason for this is suggested by our analysis. By dissolving group marriages and rearranging their members in smaller unions, paternal uncertainty can easily be reduced, and Pareto improvements hence generally be attained.

Table 1: Marriage Regimes and their Prevalences in 1267 Societies

N	%	Marriage regime	
186	14.7	monogamy	
453	35.8	occasional polygyny	1041 societies with polygyny (82.2 %)
87	6.9	common polygyny (perferentially sororal)	
501	39.5	common polygyny (non-sororal)	
4	0.3	polyandry	
36	2.8	missing	
1267	100.0	sum	

Source: Murdock's Ethnographic Atlas Codebook, 1998 World Cultures 10(1): 86-136.

6.2. Marriage Regimes: Monogamy, Polygyny, and Polyandry

The most basic classification scheme of marriage regimes is trichotomous and based on the respective number of partners that a man or woman may respectively have in a conjugal union. In monogamous marriage regimes, conjugal unions consist of only one man and one woman. In polygynous regimes, a man may have several wives, and in polyandrous regimes, one woman may have several husbands.[15] In the following, we first explore features common to all three marriage regimes and discuss some of their idiosyncratic characteristics, before turning to a formal analysis of their respective functionings and underlying causes within the context of our theoretical model.

As to common features, the most basic characteristic to note is that in all three marriage regimes, conjugal unions are intersexual in nature, i.e. they involve at least one member of each sex. This ubiquitous trait is extremely important, for it underscores that reproduction must be of central importance for the institution of marriage, as well as for individual marriage decisions. It is surprising indeed that this fact has been so little appreciated in economic theories of marriage. Not only are men and women treated largely as generic actors, but most theories also lack an explicit account of fertility decisions in their analyses (Weiss, 1997). Own offspring, however, is the only household good that requires inputs of both sexes for its production. No other motive for marriage identifed in the economics literature, such as the production and consumption of tangible household goods or the ability of inter-personal unions to engage in risk sharing, necessarily requires conjugal unions to be intersexual in nature. Neither does any of these motives arise from a market failure that can explain why societies since time immemorial have regulated the mating behavior of individuals by institutionalizing, enforcing, and promoting *intersexual* marriages. A second common feature, and one of particular importance for our line of argument, is that all marriage regimes assign exclusive reproductive property rights to members

[15] Actual mating and marriage patterns in societies, however, rarely conform to this stylized trichotomy. Not only do monogamous societies often exhibit a sizeable degree of serial polygamy, but in nearly half (43.5%) of all polygynous cultures, polygyny occurs merely occasionally. Moreover, all cultures commonly classified as polyandrous also permit polygynous unions (Daily and Wilson, 1983, p. 286-288). Finally, although most societies have not been exclusively monogamous, most marriages in fact have been (Wright, 1994, p. 91).

of a conjugal union (Wilson and Daly, 1992). For adultery is universally condemned, traditionally all the more so, however, if committed by women.[16] Similarly, premarital chastity is in general cherished if not demanded more of women than it is of men. This double standard has been and still is widely observable (Buss, 1989) and vividly underscores the ubiquity and significance of concerns about paternal uncertainty in reproduction. Finally, all marriage regimes know the legal principle of presumed paternity (see, for example, Edlund, 2005). In monogamous and polygynous marriages, a child born to a married wife is automatically recognized as her husband's offspring before the law. In polyandrous marriages, in turn, either one or several husbands are bestowed with, and consequently share, legal paternity and custodial rights and obligations (Gough, 1959, p. 32). As the latter generally includes the support of offspring, and legal recognition of fatherhood may be disputed or even denied in case a child is born out-of-wedlock, the legal paternity presumption provides a strong incentive for women to procreate in marriage only.

The relative prevalence of different marriage regimes and their individual features are no less instructive about the general importance of asymmetry in offspring recognition and reproductive capacity between the two sexes for the mating, marriage, and reproductive behavior of individuals. As noted already by Becker (1974), paternal uncertainty suffices to explain why polyandrous societies have been far less common than polygynous ones throughout human history.[17] For polyandrous marriages, by their very nature, entail a greater risk of misattributed paternity than do polygynous marriages. Concerns about paternal uncertainty can furthermore account for two prominent features of polyandrous societies. First, polyandrous marriages are often sequential in nature, i.e. share features of serial monogamy, that do allow husbands some confidence of paternity (Daly and Wilson, 1983). Second, polyandrous marriages are almost always fraternal (Low, 2007). Fraternal polyandrous marriages are conjugal unions in which several brothers are married to the same woman. While individual fatherhood in such arrangements may be highly uncertain, the biological relatedness of husbands ensures that children born to a wife in a fraternal union are at least of the same patrilineal family or blood line. Sororal marriages, i.e. marriages in which the wives of a husband are sisters, are in contrast rarely observed in societies in which polygyny is common (see Table 1). This predominance of fraternal marriages in polyandrous societies and rareness of sororal marriages in polygynous societies can easily be explained by concerns about paternity uncertainty. Asymmetry in the reproductive capacity between the two sexes likewise encourages polygyny and discourages polyandry. For limited individual female reproductive capacity constitutes a binding constraint on the number of offspring that a man may father only in polyandrous marriages, not in conjugal unions that are polygynous.[18]

[16] The cross-cultural study of Betzig (1989) finds female infidelity to be the most common cause of divorce. Female sterility ranks third in importance among the causes for marital dissolution surveyed.

[17] Only 0.3% of the 1267 societies recorded in Table 1 are polyandrous, whereas 82.2% are polygynous.

[18] As noted already by Malthus (1826, Book I, Chapter XI), limited female reproductive capacity provides an efficient check on population growth in polyandrous societies.

We next turn to a more formal analysis of monogamous, polygynous, and polyandrous mating markets within the context of our theoretical model. Primary causes of polygamous marriage regimes suggested in the literature include an unbalanced sex ratio, heterogeneity among members of a sex, and complementarities between male and female inputs to the production of household goods (Becker, 1973/74 and 1991; see also Grossbard, 1980). Our model can straightforwardly be applied to examine the influence of the first and the last of these three cases on the respective tendencies of societies to evolve either polygynous or polyandrous traits. Moreover, it can easily be extended for analyzing also the second case. As the following discussion will show, concerns about uncertain paternity and a higher male than female reproductive capacity at all times reinforce polygynous tendencies and attenuate polyandrous that may arise in the mating market.

In our model, a fall in the male / female sex ratio (ϕ) renders men more and women less promiscuous, i.e. mating becomes on average more polygynous in nature.[19] Men will have more children (as they have more female partners) and they will be more certain about their individual paternity (as female promiscuity is lower). A rise in the sex ratio, in contrast, makes women more and men less promiscuous, i.e. a relative scarcity of women causes mating to assume more polyandrous traits. Men will have less children (as they now have less female partners) and they will be more uncertain about their individual fatherhood (as female promiscuity has increased). A fall in the sex ratio, therefore, tends to promote polygynous mating $\left(N_{♂} > N_{♀}\right)$, whereas a decline encourages the spread of polyandry $\left(N_{♂} < N_{♀}\right)$. Because of asymmetries in offspring recognition and in reproductive capacity, however, the incentives of men to engage in promiscuous mating in a low sex ratio environment are generally greater than the incentives of women to engage in promiscuous mating in a high sex ratio environment. A low sex ratio society is therefore more likely to introduce a polygynous marriage regime than is a high sex ratio, but otherwise identical, society likely to settle for a polyandrous marriage regime.

Next, consider the case where members of each sex are heterogeneous in terms of their economic endowments $\left(Y_{♀}, Y_{♂}\right)$. As men in our model are valued by women for their contributions to child quality only, a more wealthy man, even if he is more promiscuous, will always be preferred by a woman to a less wealthy man, as long as he contributes more to the quality of her child. The more unequal are men, i.e. the more dispersed is wealth among potential husbands, the more will they differ in their ability to engage in promiscuous mating. Rich men may attract several female partners (engage in polygynous mating), whereas men of low economic status may have to be content with but a single female (remain monogamous), or even none (stay single). Polygynous cultures, both past and present, seem to conform well with this characterization (see, for example, Betzig, 1992/95, for evidence on ancient Greece, the Roman Empire, and

[19] As noted by Becker (1974), decidedly tilted sex ratios due to wartime deaths of men have at times encouraged the spread of polygyny. A shortage of black marriageable men, among others due to high rates of incarnation and premature death, has also been argued to underlie the generally lower marriage rates among blacks in the US (Wilson, 1987; Brien, 1997).

various European cultures in the Middle Ages).[20] Women, in contrast, are valued by men not only for their parenting, but also for their reproductive capacity. For men, therefore, a more wealthy woman, even if she invests more in child quality, does not need to be more attractive as a mating partner than a less wealthy woman if she is also more promiscuous. In addition, a wealthy woman has ceteris paribus less incentive than a wealthy men to engage in promiscous mating, as all she may gain are greater male parenting contributions. As in the case of an unbalanced sex ratio, therefore, asymmetries in offspring recognition and in the reproductive capacity between the two sexes will tend to reinforce polygynous tendencies in societies and attenuate polyandrous ones that may originate from heterogeneities in the economic endowments of women and men.

Finally, consider the case where the degree of complementarity between female and male inputs into the production of household goods changes. As noted, the only household good produced in marriage that unquestionably requires inputs ¿from both sexes are own children. In our model, the degree of complementarity between female and male inputs into the production of own kids (the only household good produced in our model) is measured by the inverse of the parameter η, i.e. the elasticity of substitution between $Q_{\male}$ and $Q_{\female}$ in the child quality function (9). The lower is η, the more dependent are men and women on each other for parenting. Because of asymmetries in offspring recognition and in reproductive capacity between the two sexes, however, child quality is of greater relative importance for the reproductive success of women than it is for the reproductive success of men. Moreover, only women may increase through extra-pair mating the number of additional contributors to the quality of their own (alleged) offspring. Men and women will therefore react differently to a fall in η. Women will seek additional male partners, and men will seek less. An increase in η has the reverse effect, as mating now becomes more attractive to men and less attractive to women. A fall in η therefore tends to promote polyandrous mating, whereas an increase in η encourages polygyny. Concerns about uncertain paternity and a higher male than female reproductive rate, however, once again attenuate the former type of mating and reinforce the latter. Evidence from polyandrous cultures suggests that harsh environmental conditions may underlie the willingness of men to nevertheless share a common a wife. Unable to support and care for own offspring individually, men simply have to collude, albeit at the risk of reproductive failure, to provide sufficient resources for offspring survival (see, for example, Crook and Crook, 1994).

Summarizing the above, in all marriage regimes does the institution of marriage serve the purpose of regulating and organizing reproduction in society. The general entitlement of spouses (and especially husbands) with exclusive reproductive property rights, the ubiquity of bans on adultery, and the universality across marriage regimes of the legal principle of presumed paternity underscore this function. Furthermore, there is ample evidence from the respective prevalences and idiosyncratic characteristics of monogamous, polygynous, and polyandrous marriage regimes

[20] Also in cultures that are not polygynous, the reproductive success of men appears to depend positively on their economic status (see Hopcroft, 2006, for an extensive literature review).

that concerns about uncertain paternity rank prominently in societies' efforts to institutionalize, enforce, and promote inter-sexual unions between the two sexes. Economic theories of marriage have altogether disregarded this pivotal regulatory function performed by marriage in societies.

6.3. The Decline of Marriage

For ages, marriage has been a virtual precondition for childbearing. In many countries, it no longer is (see, for example, Willis, 1999). The second half of the last century in particular has witnessed a marked decline of marriage, as evinced by falling marriage rates, rising rates of divorce, and growth of out-of-wedlock childbearing. At the same time, statistics on the average level of schooling, daily nutrition, and health of children suggest that child quality has improved substantially. Our model, though simple and stylized, is suitable to study qualitatively the effects of a number of legal, economic, and technological trends that are likely to underlie or at least to have contributed to this demise of marriage. These include the no-fault revolution in divorce laws, advancements in household technology, the expansion of the welfare state, and the rise in female labor force participation. These trend changes are, of course, neither exogenous, nor likely to be independent, but rather the product of yet other, potentially complex and interrelated, societal and economic changes. For our present purpose, however, we will view these changes as given, and examine their consequences for marriage and mating patterns as well as for average parental investment levels within the framework of our theoretical model. Given the postulated nature and purpose of marriage as a social institution, the following discussion focuses in particular on the respective effects these changes have on the attractiveness and effectiveness of marriage as a commitment device between partners for the bearing and rearing of offpring.

Many countries have adopted no-fault (unilateral or uncontested) divorce laws over the last decades. Prior to no fault, mutual consent among spouses or proof of spousal marital misconduct (fault) was required for divorce, and financial settlements following divorce were dependent on assessments of fault.[21] To revoke marriage, therefore, has become both more easy and less costly. In the context of our model, the no-fault revolution can be interpreted as a reduction in the level of mating costs s. As shown in Sections 5.1 and 5.2, a decline in s leads to an increase in promiscuity among previously monogamous individuals and to a decline in the level of child quality. The introduction of no-fault divorce laws is therefore predicted to have made marriage less effective as a commitment device and to have reduced parental investment in children. Supportive evidence for these predictions is provided in a number of studies for the US, which exploit time lags in the introduction of no-fault divorce laws at the state level to identify their effects on marriage and divorce patterns, as well as child quality. According to Rasul (2004), 10% of the overall decline in the marriage rate since 1970 can be attributed to the adoption of unilateral divorce laws. Furthermore, Friedberg (1998) finds the latter to explain

[21] Traditional fault grounds include, among others, emotional or physical cruelty, adultery, and desertion.

17% of the rise in divorces per capita in the period 1968 to 1988. Finally, as to child quality, Gruber (2004) shows that children born under no-fault are subsequently less well educated and have lower family incomes than children that grew up in fault states.

Improvements in household technology and the expansion of the welfare state are likely to have reduced child quality costs a and the technical dependency of women and men on each other with respect to their child quality contributions η. A decrease in a makes child quality investments more attractive for both sexes (substitution effect). However, expenditures on child quality by women and men rise less than proportionally, as some of the economic resources previously spent on child quality are now transferred to the mating market (income effect). Promiscuity, as a consequence, increases and thus paternal uncertainty (see Figure 2). Because of the latter, the male share in total child quality investments falls (see Figure 4). For a given strictness of marital arrangements, i.e. a given level of mating costs, therefore, the effectiveness of marriage in reducing paternal uncertainty declines when the costs of child quality fall. An increase in η, in turn, makes mating less attractive for women (quality maximizers) and more attractive for men (quantity maximizers). This asymmetric effect is reflected in a higher male share in total mating costs, as men reallocate resources from parenting to mating. The effect on promiscuity, however, depends on the level of mating costs. At low levels of mating costs, the equilibrium number of partners increases. At high levels, it falls. In other words, the effect of a decrease in the technical dependency of the two sexes on each other with respect to child quality depends on the strictness of marital arrangements. In line with the predictions on the effects of a fall in child quality costs a, Rosenzweig (1999) finds a significant positive effect of AFDC (Aid to Families with Dependent Children) on the probability of out-of-wedlock childbearing for low-income women in the US. Similarly, Lefebvre and Merrigan (1998) conclude that directing welfare benefits to single mothers in Canada has reduced their probability of remarriage.

In the last century, female labor supply has increased significantly to the effect that women, on average, now have an independent command over greater economic resources. In our model, a relative increase in the economic endowments of women $Y_{♀}$ leads to higher female expenditures on consumption, maternal quality investments, and mating. Because of the latter, promiscuity and the female share in total mating costs increase. Higher paternal uncertainty, in turn, causes total child quality investments of a man to fall. Overall child quality, however, increases. Marriage, therefore, becomes less effective as a commitment device and less important as a means for females to secure male contributions to child quality. Empirical evidence consistent with these predicted outcomes is, for example, provided by Blau et al. (2000), who find better labor market prospects for white women in the US to have lowered their marriage rates.

As the preceding discussion has shown, a number of recent legal, technological, and societal changes have combined forces to challenge both the attractiveness and the effectiveness of marriage. The no-fault revolution has turned marriage into a non-credible bond between individuals by making conjugal unions easier and less expensive to revoke. Technological advances in household appliances, the expansion of the welfare state, and increases in the economic resources available to women have in turn reduced the dependency of women on men for child support and parenting. With the exception of the no-fault revolution, these developments have also tended to raise average levels of child quality. In sum, therefore, marriage has increasingly been decoupled by these trends from its traditional domain, i.e. the bearing and rearing of children.

7. Conclusion

Well researched in other disciplines, such as evolutionary biology, sociology, anthropology, and psychology, sex differences have long been recognized as important determinants of both individual and group behavior. Not so in economics. Even economic theories of marriage have paid little if any attention to the fundamental fact that conjugal unions are traditionally intersexual in nature. Focusing on the advantages of joint household production and consumption to account for the existence of inter-personal unions, economic theories of marriage fail to explain why either motive necessarily requires marriage, the presence of both sexes, or a social institution to sanction such unions. Although the bearing and rearing of children is always mentioned as a primary motive for marriage, economic theories of marriage generally lack an explicit account of fertility decisions in their analysis. They also fail to provide a rationale for why society should take any interest at all in the regulation of reproductive behavior. The traditionally intimate relationship between childbearing and marriage, however, suggests that fertility considerations must have been always central to both individual marriage decisions and the very role that the institution of marriage performs in societies.

This paper has developed a first microeconomic foundation for the institution of marriage. In our account of the origin and purpose of this institution, fertility considerations both at the individual and societal level are of primary importance. Based on a model of mating behavior, reproduction, and parental investment in children, we have shown that marriage as an institution can be explained as a societal response to mating market failure that arises from incomplete information on individual paternity. By circumscribing promiscuity, the institution of marriage makes paternity of men more certain and induces them to invest more in their putative offspring. Able to raise the welfare of both women and men, as well as average levels of parental care, the institution of marriage can realize Pareto improvements that we believe are central to an understanding of why societies around the world have at all times circumscribed the mating behavior of individuals by endorsing and enforcing marriage as the preferred, if not the only acceptable form of union between the two sexes. Our foundation of the institution of marriage is consistent with both the traditional role of conjugal unions as the primary place for the bearing and rearing of children in societies, and the general requirement of fidelity between spouses.

For millennia an ubiquitous and central institution in societies, marriage has recently been subject to a number of fundamental legal, economic, and societal changes that challenge both the role and the effectiveness of this long-standing institution. The no-fault revolution has turned marriage into a non-credible bond between individuals by making conjugal unions easier and less expensive to revoke. Moreover, technological advances in household appliances, the expansion of the welfare state, and increases in the economic resources available to women have reduced the dependency of women on men for child support and parenting. In combination, these trends have led to a decoupling of marriage from the bearing and rearing of children. Whether or not these changes have the potential to permanently alter the role of marriage in societies is yet not foreseeable. The recent marked trend decline in marriage rates in many countries, however, suggests that the challenge posed by these profound changes to the institution of marriage is a serious one indeed. Moreover, a new profound challenge may yet lie ahead, arising from technological advances in the area of genetic paternity testing. For centuries, men had to rely on mate guarding or marriage to reduce the risk of cuckoldry, and on but indirect cues to ascertain their fatherhood ex post, such as the physical resemblance to their putative offspring. Genetic paternity testing, if universally applied, would render such measures obsolete. By eliminating asymmetry in offspring recognition, paternal uncertainty would cease to be a potent source of mating market failure. Societies would have less reason to circumscribe the mating behavior of individuals, and the institution of marriage would loose yet another, if not the most powerful argument strengthening its case.

Appendix A. Social Optimum

Denote by ξ and $(1-\xi)$ the respective weights a social planner attaches to the utility of the representative woman and man. We first characterize the social optimum when the sex ratio is balanced, and then describe optimal mating market outcomes when one sex outnumbers the other.

If $\phi = 1$, so that $N = N_{♀} = N_{♂}$, a social planer would increase the number of mating partners per individual, $N \in \mathbb{N}_0$, as long as the following inequality holds:

$$\begin{aligned}&\xi(U(C_{♀}^{N}) - U(C_{♀}^{N+1})) + (1-\xi)(U(C_{♂}^{N}) - U(C_{♂}^{N+1})) \leq \\ &\xi(V(1, Q^{N+1}) - V(\min\{N,1\}, Q^{N})) + (1-\xi)(E_{N+1}[V(K_{♂}, Q^{N+1})] - E_{N}[V(K_{♂}, Q^{N})]),\end{aligned} \tag{A1}$$

i.e. the weighted sum of losses in female and male non-reproductive utility is equal to or smaller than the weighted increase in the utility of women and men from reproduction when resources are transferred from non-reproductive consumption to the mating market and to parental investment. Note that in contrast to equations (14) and (17), increasing N above 1 (excess mating) does not increase the expected utility from reproductive success per man because the planner internalizes the spillover effects of promiscuity on the probability of fatherhood δ and on total male quality contributions $Q_{♂}$. Concavity of V with respect to K implies that E_N, which operates under the binomial distribution with parameters N and $\frac{1}{N}$, provides ceteris paribus a higher level of utility than E_{N+1}. While the expected number of offspring is constantly one, its variance, which is equal to our measure of paternal uncertainty $(1-\frac{1}{N})$, increases in N which leads to a loss in male utility. As a consequence, total male quality contributions also decline when paternal uncertainty increases, i.e. $Q_{♂}^{N} > Q_{♂}^{N+1}$. Hence, there are no social benefits from excess mating and the optimal N is either 0 or 1. Reproduction, i.e. $N = 1$, is socially optimal if:

$$V(1,Q) \geq \xi(U(Y_{♀}) - U(Y_{♀} - s_{♀} - a_{♀}Q_{♀})) + (1-\xi)(U(Y_{♂}) - U(Y_{♂} - s_{♂} - a_{♂}Q_{♂})), \quad \text{(A2)}$$

where $V(1,Q)$ denotes the joint utility of women and men from reproduction when paternity is certain. Assuming (A2) holds, socially optimal child quality investments have to satisfy:

$$\frac{a_{♀}}{a_{♂}} \frac{U'(Y_{♀} - s_{♀} - a_{♀}Q_{♀})}{U'(Y_{♂} - s_{♂} - a_{♂}Q_{♂})} = \frac{\alpha}{1-\alpha} \left(\frac{Q_{♂}}{Q_{♀}}\right)^{\frac{1}{\eta}}. \quad \text{(A3)}$$

Condition (A3) is obtained by dividing the respective first order necessary conditions of the social planer for female and male contributions to child quality. It requires that the ratio of female to male marginal child quality costs, transformed in utility units, is equal to the technical rate of substitution between female and male contributions in the child quality function (9). Note that the weights ξ and $1-\xi$ do not appear in the respective first order necessary conditions for $Q_{♀}$ and $Q_{♂}$. Moreover, because of the public good nature of child quality, V_Q is identical for women and men and therefore irrelevant for the determination of the socially optimal level of child quality investments. Mating costs s are divided among women ($s_{♀}$) and men ($s_{♂}$) by the social planer such that the weighted marginal utilities of both sexes with respect to non-reproductive consumption are equal:

$$\xi U'(Y_{♀} - s_{♀} - a_{♀}Q_{♀}) = (1-\xi)U'(Y_{♂} - s_{♂} - a_{♂}Q_{♂}). \quad \text{(A4)}$$

Using (A4), the condition for optimal child quality contributions (A3) simplifies to:

$$\frac{1-\xi}{\xi} = \frac{a_{♂}}{a_{♀}} \frac{\alpha}{1-\alpha} \left(\frac{Q_{♂}}{Q_{♀}}\right)^{\frac{1}{\eta}}. \quad \text{(A5)}$$

Condition (A5) requires the ratio of marginal quality costs times the technical rate of substitution to equal the ratio of the respective weights attached by the social planer to the utilities of men and women. Note that the degree of substitutability between female and male contributions η plays no role, if for instance $\alpha = \xi = \frac{1}{2}$ and $a_{♀} = a_{♂} = a$. In this case, both parents contribute equally to total child quality.

If $\phi \neq 1$, socially optimal allocations on the mating market will be different. Optimality, however, still requires mating expenditures not to exceed the minimum necessary for reproduction and paternity to be certain. In other words, a woman will be matched to but a single man at most. If men outnumber women ($\phi > 1$), this implies that a fraction $(1-\phi^{-1})$ of men has to remain childless. If, in contrast, women outnumber men ($\phi < 1$), then it will not only be optimal for all men to reproduce, but even for some of them to father more than one child with more than one woman.

Appendix B. Continuous Choice

For expository and analytical reasons, we have changed to a continuous choice of mating partners in Section 5. Given our parametrization of the utility function (19), this change implies the following first order necessary conditions for the representative female. Her optimal investment in child quality $Q_♀$ has to meet the condition:

$$\gamma a_♀ \left(Y_♀ - s_♀ N_♀ - a_♀ Q_♀\right)^{-\sigma} = (1-\gamma)\alpha\theta \left(\frac{Q}{Q_♀}\right)^{\frac{1}{\eta}} Q^{\theta-1}, \tag{B1}$$

and her optimal continuous choice of male mating partners $N_♀$ has to satisfy:

$$\gamma s_♀ \left(Y_♀ - s_♀ N_♀ - a_♀ Q_♀\right)^{-\sigma} = (1-\gamma)(1-\alpha)\theta \left(\frac{Q}{N_♀ q_♂}\right)^{\frac{1}{\eta}} q_♂ Q^{\theta-1}. \tag{B2}$$

The expected utility of a man from reproduction is determined by the κ-th moment of the binomial distribution with $N_♂$ draws (female partners) and probability of success (fatherhood) δ:

$$E[V(K_♂, Q)] = (1-\gamma)Q^\theta \sum_{K_♂=0}^{N_♂} \mathrm{Prob}(K_♂; N_♂, \delta) K_♂^\kappa. \tag{B3}$$

As there is no closed-form representation of the κ-th moment of the binomial distribution, we apply the delta method. Specifically, we use a third-order Taylor expansion of equation (B3) around the representative man's expected number of offspring $K_♂^e = N_♂\delta$ (see equation (6)) to approximate the utility he receives from children as follows:

$$\begin{aligned} &V(K_♂, Q) \approx \\ &V(K_♂^e, Q) + (K_♂ - K_♂^e)V_K(K_♂^e, Q) + \tfrac{(K_♂ - K_♂^e)^2}{2} V_{KK}(K_♂^e, Q) + \tfrac{(K_♂ - K_♂^e)^3}{6} V_{KKK}(K_♂^e, Q). \end{aligned} \tag{B4}$$

A third-order expansion is necessary because of the skewness of the binomial distribution that determines the reproductive success of men. Only for symmetric distributions, i.e. for the special case where $\delta = \frac{1}{2}$, will skewness have no influence on the utility maximization problem of men. For given $N_♂$ and δ, the expected utility the representative man derives from children is given by:

$$E[V(K_♂, Q)] \approx (1-\gamma)Q^\theta (K_♂^e)^\kappa \left[1 + \frac{(1\text{-}\delta)\kappa(\kappa\text{-}1)}{2(K_♂^e)} + \frac{(1\text{-}\delta)(1\text{-}2\delta)\kappa(\kappa\text{-}1)(\kappa\text{-}2)}{6(K_♂^e)^2}\right]. \tag{B5}$$

Hence, the marginal change in the expected utility a man derives from children due to a marginal increase in the number of his female partners $N_{♂}$ is:

$$\frac{\partial E[V(K_{♂},Q)]}{\partial N_{♂}} \approx \frac{(1\text{-}\gamma)Q^{\theta}(K^e_{♂})^{\kappa}}{N_{♂}}\left[\kappa+\frac{(1\text{-}\delta)\kappa(\kappa\text{-}1)^2}{2K^e_{♂}}+\frac{(1\text{-}\delta)(1\text{-}2\delta)\kappa(\kappa\text{-}1)(\kappa\text{-}2)^2}{6(K^e_{♂})^2}\right]. \tag{B6}$$

In the continuous choice setting, expansions (B5) and (B6) allow to approximate the following first order necessary conditions for men with respect to $q_{♂}$ and $N_{♂}$:

$$\gamma a_{♂} N_{♂}\left(Y_{♂}-s_{♂}N_{♂}-a_{♂}N_{♂}q_{♂}\right)^{-\sigma}=\frac{(1-\alpha)\theta}{Q}\left(\frac{Q}{Q_{♂}}\right)^{\frac{1}{\eta}}E[V(K_{♂},Q)], \tag{B7}$$

$$\gamma\left(a_{♂}q_{♂}+s_{♂}\right)\left(Y_{♂}-s_{♂}N_{♂}-a_{♂}N_{♂}q_{♂}\right)^{-\sigma}=\frac{\partial E\left[V\left(K_{♂},Q\right)\right]}{\partial N_{♂}}. \tag{B8}$$

The solution to the model is described by the first order necessary conditions (B1) and (B2) for females, their counterparts for males (B7 with B5) and (B8 with B6), the market-clearing condition for the mating market (11), and the mating cost constraint (12). This system of equations is solved for $Q_{♀}$, $N_{♀}$, $q_{♂}$, $N_{♂}$, $s_{♀}$, and $s_{♂}$.

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