Primogeniture, Monogamy and Reproductive Success in a Stratified Society

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Abstract. This paper explores the workings of stratified societies in which there is primogeniture and where the nobility practice monogamous marriage with a double standard of sexual fidelity. The paper models a simple stratified society and defines the reproductive values of male and female nobility relative to that of commoners. It goes on to explore implications of the hypothesis that preferences have evolved to favor maximization of reproductive value. This hypothesis is tested against fragmentary data from ancient civilizations and quite detailed information about the British aristocracy in the seventeenth and eighteenth centuries. This work has been heavily influenced by theoretical discussions and empirical evidence found in the writings of an anthropologist, Laura Betzig, and an historian Lawrence Stone.

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According to Laura Betzig (1993) , the first six great ancient civilizations for which reasonable historical records exist were Mesopotamia, Egypt, Aztec Mexico, Inca Peru, India, and China. All were highly stratified societies with extreme inequality of wealth and with extreme inequality of male reproductive success. The wealthy nobility in each of these societies practiced monogamous marriage, but highly polygynous mating. The British aristocracy of late medieval and early modern times likewise had monogamous marriage and polygynous mating. Lawrence Stone (1965) reports that:

> "In England as in all other European societies, marriage gave the husband monopoly rights over the sexual services of the wife, but conferred on the wife no reciprocal monopoly over the husband. In the early sixteenth century open maintenance of a mistress–usually of lower-class origins–was perfectly compatible with a respected social position and a stable marriage. Peers clearly saw nothing shameful in their liaisons, and up to about 1560 they are often to be found leaving bequests to bastard children in their wills. In practice, if not in theory, the early-sixteenth-century nobility was a polygamous society.

Although they mated polygynously, noblemen in each of these civilizations married monogamously and practiced primogeniture (Betzig, 1993). That is, they selected a single wife who was the only woman entitled to bear the nobleman's "legitimate" offspring–potential heirs his power and fortune. If the wife should fail to bear heirs, she might be replaced by a successor, but her legitimate progeny could not be displaced by the nobleman's "illegitimate" offspring. Not only was the greatest part of the duke's inheritance restricted to the offspring of a single wife, but among her children inheritance was concentrated on the oldest son. In the absence of a legitimate son, inheritance was sometimes passed to the oldest legitimate daughter, sometimes to a brother or nephew and occasionally to the son of a favored concubine. Some, but not all, of the legitimate daughters would be married to the heirs of other noblemen.

All of these societies successfully maintained and replicated themselves over periods of several centuries. Betzig reports that of the six early civilizations, "Each seems a local response to local conditions; none seems to have been a product of conquest or diffusion from an other civilization." This suggests that stratified societies in which the wealthy practice monogamy, primogeniture and a sexual double standard are quite likely to arise and once arisen can be very stable. It is therefore interesting to seek the common threads in human motivation that held these structures together, so that century after century, the actors in each of these dramas continued to play out the roles assigned to them by societal institutions.

This paper tests the hypothesis that in stratified societies with monogamy and primogeniture, individual actions are consistent with each actor maximizing his or her genetic influence on future generations. In the first section of the paper we lay the theoretical groundwork for testing this hypothesis; constructing a simple model of a two-class society, introducing a recursively defined notion of "reproductive value" and calculating some simple equations that specify the reproductive values of noblemen and their wives and children relative to the reproductive value of commoners. These equations are expressed in terms of demographic parameters that can in principle be estimated from historical data about actual societies. The second section of the paper investigates the data available in historical sources for the ancient civilizations and for early modern England. These data are used to calculate numerical estimates of the reproductive values of each type of nobility. In the third section of the paper, the theory developed in the first section is confronted with historical data to test the hypothesis that the English aristocracy of the seventeenth and eighteenth centuries were acting in a way consistent with maximization of their reproductive value.

Section I.   Theoretical Foundations

I.1.   An evolutionary approach to inheritance and reproduction

On the evolution of genetically transferred preferences

One of the strongest forces motivating human activity is the desire to produce descendants. In a Darwinian view of human preferences, this is as it must be. If preferences are passed on by Mendelian inheritance, then the most common preferences in the current population are inherited from those members of the ancestral population who passed on the most genes. The preferences one expects to observe in the current population are, therefore, those that tended in the past to maximize one's genetic contribution to future populations.[1]

This paper explores the implications of the hypothesis that individual preferences relevant to reproduction and inheritance are determined genetically and hence that the equilibrium population consists of individuals who act so as to maximize their genetic representation in the population in the long run.[2]

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[1] A similar view of the evolution of human preferences is taken by Rogers (1994) who offers an evolutionary theory of time preference and Robson (1994) who offers an evolutionary theory of attitudes toward gambles and risk. Bergstrom (1994) presents a theory of the evolution of altruism toward siblings and Bergstrom and Stark (1993) present a series of models in which there is Darwinian selection for cooperative behavior in prisoners' dilemma games.

[2] Undoubtedly, many aspects of our preferences are not genetically, but "culturally" inherited from those around us. With cultural inheritance, as with genetic inheritance, preferences are passed from one generation to the next according to specific orderly processes of interaction. To the extent that culture is transmitted from parents to offspring, the calculus of inheritance is very similar to that of genetic inheritance. Of course cultural inheritance allows for many other methods of transmission, since ones

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For preferences that are inherited genetically, the special structure of Mendelian inheritance has remarkably strong implications for the relative values that individuals place on their own reproduction and that of their kin. The *theory of kin-selection*, developed by William Hamilton (1964) spells out these implications in detail. According to Hamilton's theory of kin-selection, the genes that succeed under natural selection are those that induce individuals to take actions that maximize a weighted average of their own fertility and that of their kin; where the weight that one places on a relative's fertility is one's *coefficient of relationship* to the relative.[3] The coefficient of relationship between two individuals is defined by biologists to be the probability that the genes found in any genetic locus in the two individuals are both copies of a gene found in a common ancestor. (See, for example, Trivers (1985).) According to Mendelian theory, the coefficient of relationship between a parent and child is 1/2 and that between a parent and grandchild is 1/4. The coefficient of relationship between full siblings is 1/2, between half-siblings it is 1/4 and between cousins it is 1/8.

Many economists will find the hypothesis that people seek to maximize their reproductive success a hard assumption to swallow. While they would concede that humans seem to display some interest in helping their kinfolk and in producing healthy children, they would be reluctant to concede that reproduction is "all there is". After all, people care about other things, like status, power, and material comfort. A zealous defender of the genetic theory would counter that desires for status, power, and comfort evolved, much as did the desire for sexual satisfaction, because the achievement of these instrumental targets usually contributed positively to the ultimate goal of genetic reproduction. This paper does not need to take such a hard-and-fast position. The analysis presented here will apply almost intact, even if genetic transmission is only one of the major motives guiding individual action. The crucial assumption is that to the extent that people care about reproduction, this concern is adequately represented by the calculus of genetic relationship.

Since natural selection of preferences must certainly be a very slow-moving process, and since through most of its evolutionary past, our species has probably lived in relatively simply-organized communities of hunter-gatherers, it is reasonable to ask why we would expect that human preferences would have evolved to produce actions that maximize reproductive success in complex, hierarchical societies. The answer that I find appealing is that our reproductive behavior is controlled not by genetically hard-wired, specific responses,

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"cultural parents" need not always be one's genetic parents. It would be possible in principle to specify a theory of culturally inherited preferences which led to empirical predictions different form the predictions based on a theory of genetically inherited preferences. Interesting models of cultural inheritance are examined in the (culturally) seminal work of Cavalli-Sforza and Feldman (1981) and Boyd and Richerson (1985). Additional examples are found in Bergstrom and Stark (1993).

[3] Hamilton's original formulation required that the game played between relatives have payoff functions that depended in a special additive way on the actions of agents. Bergstrom (1994) shows how Hamilton's ideas can be extended to a much more general class of games. The games that are studied in this paper have Hamilton's additive structure.

but by preferences that have evolved to lead to successful reproduction in a wide variety of environments. Our species has succeeded in adapting to extremely diverse physical and social environments. Yet, within this diversity, many aspects of personality and motivation that are critically related to reproduction seem remarkably constant. Examples of such universality are found in the nature of sexual desire in men and in women, in bonding between parents and their offspring, in the ability to love and to empathize with one's mate and children, and in cravings for affection and urges for power. It is worth considering the view that these psychological proclivities are coordinated in such a way as to make us act approximately like reproductive value maximizers, even in environments that differ dramatically from the communities in which our preferences evolved.

I suspect that a great deal of human behavior can not be adequately explained by a theory of genetically transmitted preferences and that the theory will ultimately have to be augmented by the inclusion of *cultural* inheritance of preferences. But investigating the consequences of the simple hypothesis that natural selection has produced agents with preferences for maximizing their genetic success seems a good starting point. Even if this hypothesis turns out to make poor predictions, the way in which it fails may help us to find better hypotheses.

The Trivers-Willard theory and differential inheritance in stratified societies

The eminent biologist and statistician, Sir Ronald A. Fisher (1930), proposed an elegant explanation of why sexually reproducing species typically produce equal numbers of male and female offspring. Since every child has one male parent and one female parent, if the ratio of male to female births is anything other than 1:1, then (assuming that mating is random) the expected number of offspring born to a member of the rarer sex would exceed the expected number born to a member of the opposite sex. Therefore natural selection would act in favor of individuals with a genetic predisposition to produce relatively more members of the rare sex. The only equilibrium for this process is one in which the sexes are produced in equal numbers.

Biologists Robert Trivers and D. E. Willard (1973), introduced an interesting refinement of Fisher's theory. They observed that in most sexual species, including humans, mating is not random. The variance of the number of children fathered by a male is much greater than the variance of the number of children born to a female. Regardless of the number of males to whom she has sexual access and regardless of the amount of resources she controls, the number of offspring that a human female can produce is constrained within rather narrow bounds. In contrast, a male, if given access to sufficient numbers of females and sufficient amounts of resources is capable of producing a very large number of offspring. In many species, males who control greater amounts of resources also command sexual access to greater numbers of females. Trivers and Willard suggest that in a species where relatively prosperous parents are likely to inherit the prosperity of their parents,

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there would be an evolutionary advantage to having the ability to vary the sex ratio of offspring with one's own relative prosperity. This phenomenon, which has come to be known as the Trivers-Willard effect, has been observed in a number of animal species.

An anthropologist, Mildred Dickemann (1979) suggested that in stratified human societies, cultural, rather than physiological manipulation of the sex ratio may be of primary importance. She observed that the Trivers-Willard theory predicts that among the rich, parents will tend to favor males, while among the poor, females may be more valuable than males. Dickemann provides historical evidence from 19th century India and China and from medieval Europe of the prevalence of female infanticide and of differential parental investment in favor of males among the upper classes. She observed that in many highly stratified polygynous societies, a female who marries a high status male must bring a dowry, while in the lower classes, males can obtain wives only by paying a bride price.[4]

I.2.   A Model of a two-class society

For our formal model, we make the drastic simplification of assuming that there are only two social classes. The model is certainly too simple to be an accurate picture of the great civilizations of history, which typically had an elaborate hierarchy of social classes. A more thorough model would recognize this hierarchy and would specify patterns of individual and family mobility within it. Despite its shortcomings, the two-class model seems to be rich enough to capture most of the essential features of the institutions of monogamous marriage, primogeniture, and polygynous mating and it has interesting implications that are not apparent from intuition or informal argument. Where these implications correspond to features of actual societies, this model helps us to understand just why these effects are found. Where the implications do not correspond to reality, the model's failures may suggest directions for deeper analysis based on better assumptions.

The two social classes will be called *nobles* and *commoners.* The male head of a noble family is called *the duke.* The duke inherits an estate on the death of his father. The duke becomes life tenant to the estate. He can spend the income from the estate, but he is not allowed to sell or subdivide it. The duke is allowed to have only one wife at a time, *the duchess.* The duke's only "legitimate" children are those born to him and the duchess. Divorce is not permitted, though if the current wife should die, the duke is allowed to remarry. Any children born to a second or later marriage will be classified as legitimate for purposes of succession. When the duke dies, he will be succeeded by his oldest surviving legitimate son if he has one. If he has no legitimate surviving sons, the succession passes to one of his other descendants or kin according to predetermined rules of succession. The duke may maintain concubines, mistresses, or servants by whom he

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[4] Gaulin and Boster (1990) examined the 1297 societies listed in Murdock's *Ethnographic Atlas* Murdock (1967) and found dowry to be common in stratified monogamous societies and extremely rare in all other societies. They find a total of 72 societies that are monogamous and highly stratified. Of these, 27 have dowries. Of the remaining 1225 societies, only 8 have dowries.

sires children and he may pay for the care and upbringing of these "bastards", but the bastards will be commoners rather than nobility and will have no claim to inheritance of the ducal estate.

The younger brothers of the current duke belong to the nobility and serve as back-up heirs. They are given living allowances but will not inherit the estate unless the duke dies without heirs among his legitimate children. Their children have no claim on the ducal estate, and revert to the status of commoners. Unless the daughter of a duke marries the heir to an estate, her children will also be commoners. There will be competition among noble parents to have their daughters marry heirs to ducal estates. Accordingly, a duke's daughter will get to be a duchess in later life only if her parents give her a dowry sufficiently large to induce a current or future duke to marry her.

Occasionally the family succession fails. This may happen because the current ducal family fails to produce an heir in the line of succession, because rivals employ political means to wrest the estate away from its current ruling family or because through financial mismanagement or bad luck (and despite social norms) the duke manages to lose his estate. The number of dukes in the model is kept constant by the assumption that when a noble family fails to produce a successor, a commoner becomes the duke.

Definition of reproductive values

A central concept for the theory developed in this paper is that of an individual's *reproductive value*, which will be defined as a specific measure of reproductive success. We set the scale for measurement of reproductive values by assigning a reproductive value of 1 to commoners. The reproductive value of a duke (duchess) is then defined to be the expected ratio, in populations of the distant future, of the number of genes descended from the duke (duchess) to the number of genes that are descended from a commoner.

An individual's reproductive value is not the same as the expectation of the proportion in distant future populations of genes that are *identical to* to that individual's genes. One may have a gene that is identical to a gene possessed by a member of a future generation, not because the latter gene is copied through a line of descendants from the former, but because both genes are inherited from a common ancestor. Hamilton's theory of kin-selection has it that natural selection will favor genes that induce people to act as if they were attempting to maximize the number of genes in the long run population that are identical to their own. Borrowing language that parallels Hamilton's, we define a person's *extended reproductive value* to be a weighted average of that individual's own reproductive value and the reproductive value of relatives who are not the individual's descendants, where the weights on kin are equal to their coefficients of relationship.[5] According to this

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[5] One simple rule of calculation excludes the possibility of double-counting. *In any definition of extended reproductive value, do not count both an individual and a descendant of that individual.* The descendant's reproductive value is already added in to the reproductive value of his ancestor.

theory, people would act so as to maximize utility functions that are a weighted average of their own reproductive values and of kin who are their descendants.

Since extended reproductive values are weighted sums of individual reproductive values, it must be that calculating individual reproductive values is also central to the theory of kin-selection. In the theory of kin-selection, an individual's reproductive value serves as an "aggregator function" that determines whether an individual will favor a tradeoff in the fertility of one descendant for that of another if these changes have no effects on the reproductive values of his siblings and cousins.[6]

I.3. Calculating reproductive values in a two-class society

The reproductive value of dukes, duchesses and common folk

A duchess is assumed to have children only by her husband, the duke. Hence her genes are passed to future generations only through the duke's legitimate children. If she has at least one son who survives until the duke's death then she will be the mother of a future duke. If she has daughters, then if one of her daughters marries a duke, she will be the mother of a future duchess. She may also have additional children who do not become dukes or duchesses, but pass their genes on to either legitimate or illegitimate offspring. Since the duke is the father of each of the duchess's children, he has all of the opportunities for passing on his genes that the duchess does. In addition, he has the opportunity to pass on his genes to bastard offspring, through his mistresses, concubines, and paramours.

We are going to consider a stationary environment and a population that is in steady-state equilibrium, with the size and composition of the population remaining constant over time and with the institutions of marriage, mating, and inheritance remaining unchanged. In this model it will turn out that the reproductive value of a commoner remains constant over time and so does the reproductive value of a duke or of a duchess. We normalize the measurement of reproductive values by assigning a reproductive value of 1 to commoners at any time. Let us define V_m be the reproductive value of a married duke and let V_f be the reproductive value of a duchess.

Since part of a duke's or duchess's reproductive value lies in the possibility of producing little dukes and duchesses, calculating the reproductive values of the nobility is the kind of problem that is known as "recursive". That is, in order to know the reproductive value of a current duke or duchess, we need to know the reproductive value of a duke or duchess in the next generation, and so on *ad infinitum*. To the mathematically uninitiated it

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[6] Where there is inbreeding, one's own descendants may also be descendants of one's siblings. For example if a duke's son marries his sister's daughter, then their children are the duke's grandchildren and are also the duke's brother's grandchildren. The duke's grandchildren by this marriage contribute the same amount to the duke's reproductive value as his grandchildren by a child who marries an unrelated person. However, since these grandchildren add to his brother's reproductive value as well as to his own, he would care more about them than about grandchildren from the marriage of one of his children to an unrelated individual .

might seem that a self-referential problem like this can not have a determinate solution. Fortunately, this problem is neatly solved for societies in a steady-state equilibrium by the mathematical technique of *dynamic programming*. In fact the special examples studied here can be handled even more simply, with the elementary mathematics of simultaneous linear equations.

Calculating reproductive values in a bare-bones special case

Let us begin with a much-simplified special case. Although this special model will soon be abandoned in the interest of realism, the simplifications make it easy to grasp the logic of recursively defined reproductive values. We make the following temporary assumptions which will be discarded in the next section.

(i) If the duke and duchess have a surviving son, he will inherit the estate. Otherwise the estate will go to a brother or cousin of the duke.

(ii) The duke's legitimate nonsuccessors–younger sons and daughters who don't marry dukes–produce no offspring.

iii) If the duke's first wife dies without leaving him an heir, none of his descendants will succeed him.

We also assume that if the duke has surviving daughters, he provides a dowry sufficient for exactly one daughter to marry a ducal heir and become a duchess. Let Π be the probability that a duke and duchess have at least one legitimate son who survives to adulthood, marries, and succeeds his father as duke. Assume that the probability that they produce a daughter who becomes a duchess is also Π. Let B be the expected number of illegitimate offspring sired by the duke.

In this simple model, there are only two means by which a duchess can pass her genes to posterity. She can have a son who becomes a duke and she can have a daughter who becomes a duchess. Her coefficient of relationship to each of her children is $1/2$. If she produces a son who becomes duke and marries, his reproductive value, like that of his father, will be V_m. If she has a daughter who marries and becomes a duchess, her reproductive value, like that of her mother, will be V_f. The expected reproductive value that she gains from the possibility of giving birth to a future duke is $\frac{1}{2}\Pi V_m$ and the reproductive value that she gains from the possibility of being the mother of a future duchess is $\frac{1}{2}\Pi V_f$. Her total reproductive value is given by:

$$V_f = \frac{1}{2}\Pi V_m + \frac{1}{2}\Pi V_f. \tag{1}$$

The duke can pass genes to future generations either through legitimate heirs or through his bastard offspring. The reproductive value that he gains through legitimate heirs must be the same as the total reproductive value of the duchess. In addition, if the expected

number of bastards that he sires is B, he adds $B/2$ to his fertility since each bastard has reproductive value of 1 and his coefficient of relationship to his children is $1/2$. Therefore the duke's reproductive value is given by:

$$V_m = V_f + \frac{B}{2}.$$ (2)

The two simultaneous linear equations (1) and (2) can be solved for the reproductive values V_f and V_m, expressed as functions of the parameters Π and B. These are:

$$V_f = \frac{B\Pi}{4(1 - \Pi)}$$ (3)

$$V_m = \frac{B(2 - \Pi)}{4(1 - \Pi)}$$ (4).

Equations 3 and 4 reveal a remarkable fact. If they sired no bastards, the nobility would have no reproductive value. Though a duchess may not enjoy sharing her husband's resources with his concubines and bastards, her long run genetic yield depends entirely on the production of bastards by her male descendants. The reason this is true is quite easy to understand. Since in each generation, there is a positive probability, $1 - \Pi$, that the legitimate line of succession will end with the current duke, the expected contribution to the gene pool from the legitimate offspring of the current duke approaches zero in the limit as the distance into the future gets large.

So long as $B > 0$, these equations also allow us to find a strikingly simple expression for the *ratio* of the reproductive value of a duke to that of a duchess.

$$\frac{V_m}{V_f} = \frac{2 - \Pi}{\Pi} = \frac{2}{\Pi} - 1.$$ (5)

It is not surprising to see that since dukes can produce children both within and outside of marriage and duchesses produce children only within the marriage, it follows from equation 5 that $V_m/V_f > 1$ if $\Pi < 1$. More interestingly, the ratio V_m/V_f is independent of the expected number of bastards and this ratio is a decreasing function of the probability Π that the duke has an heir.

Accounting for the fertility of legitimate nonsuccessors and the remarriage of dukes

It is important on both theoretical and empirical grounds to enrich the model to account for the fertility of the "legitimate nonsuccessors", those legitimate sons and daughters of a duke and duchess who do not themselves become dukes or duchesses. The fertility of legitimate nonsuccessors born to the duke and duchess contributes an equal amount to the reproductive value of each parent. Let G' be the expected number of children (legitimate or

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not) who are born to the legitimate nonsuccessor children of a duke and duchess. Each of these grandchildren has a coefficient of relationship of 1/4 to the duke and to the duchess. Since the offspring of legitimate nonsuccessors are assumed to be commoners,[7] each of these grandchildren has a reproductive value of 1. Therefore the reproductive value that a duke or duchess gains directly from the fertility of their legitimate nonsuccessor children is $G'/4$. Expression 1 for a duchess's reproductive value is therefore generalized as follows:

$$V_f = \frac{1}{2}\Pi V_m + \frac{1}{2}\Pi V_f + G'/4. \tag{1$'$}$$

The possibility of remarriage introduces further asymmetry between the reproductive values of dukes and duchesses. If a duke remarries on the occasion of the death of a wife who has not left him a surviving son or daughter, then he may produce legitimate heirs who are not descendants of his first duchess. Here we assume that a duchess who is widowed does not have additional children.[8] Because of the asymmetry in rules of remarriage, the duke will have a higher probability than a duchess of producing legitimate heirs and will also have a higher expected number of legitimate nonsuccessor children.[9] Then the expected number of legitimate offspring produced by a duke is $(1 + \theta)$ times the expected number produced by the duchess whom he first marries. Equation (2) should now be replaced by

$$V_m = (1 + \theta)V_f + \frac{B}{2} \tag{2$'$}$$

The simultaneous equations 1$'$ and 2$'$ can be solved to find independent expressions for V_f and V_m:

$$V_f = \frac{B\Pi + G'}{4(1 - \Pi) - 2\Pi\theta} \tag{3$'$}$$

$$V_m = \frac{B(2 - \Pi) + (1 + \theta)G'}{4(1 - \Pi) - 2\Pi\theta} \tag{4$'$}.$$

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[7] A useful extension of this model would assign legitimate grandchildren of nobles who are not in the line of succession would belong to a social class just below that of the ducal families, but above the social class of commoners.

[8] Unlike the asymmetry in biological limitations on the fertility of males and females, this source of asymmetry appears to be largely a matter of convention. The assumption that heirs to the ducal estate can not come from a later marriage of the duchess is realistic for the British nobility and for many other systems of primogeniture, but is probably not universal. The assumption that duchesses can not produce legitimate nonsuccessor children on the death of their husbands is rather arbitrary. Both of these assumptions could be relaxed in a more detailed model.

[9] For simplicity, let us assume that the probability θ that the duke's firstborn surviving son is born not to his first wife but a later wife is the same as the probability that his first surviving daughter is born to a later wife and that the expected number of legitimate nonsuccessors born to a duke by second or later wives is θG.

The possibility of remarriage for dukes contributes to a duke's reproductive value both directly through its effect on his own fertility and indirectly because it increases the reproductive value of his successors. Perhaps more surprisingly, we see from equation 3′ that the reproductive value of a duchess is an increasing function of θ. This is true because although the possibility of her husband's remarriage in the event of her death does not increase her own reproductive value, the possibility that *her son* will remarry in the event of *his* wife's death does increase the reproductive value of a duchess.

Indirect inheritance and the rules of succession,

If a duke and duchess do not produce a surviving legitimate son, the estate is often passed by *indirect inheritance* to a nephew or other relative according to established rules of precedence. With indirect inheritance, so long as there are precedence is well-specified, it remains possible to use the recursive methods to calculate the reproductive value of dukes and duchesses. In general, the necessary recursive equations will now require calculations are at least "two generations deep".

Here we show how reproductive values are calculated under a specific set of rules: If the duke has at least one legitimate surviving son, the estate passes to the oldest of them. If the current duke does not have a legitimate surviving son and if he has at least one legitimate brother who has a legitimate son, succession passes to the nephew who is the oldest legitimate son of the oldest of the duke's legitimate brothers. If the duke has no legitimate brothers with legitimate sons but has a sister with has a legitimate son, succession passes to one of the sisters' sons who does not inherit a ducal estate from his own father.[10] Finally, if the duke has no legitimate grandchildren, the estate passes to descendants of the duke's brothers, according to the same rules of priority.[11]

Where the rule of succession depends on the distribution of grandchildren as well as of children, the most direct way of calculating the reproductive value of a duchess is to calculate the expected reproductive value of all of her grandchildren and divide by 4, since her coefficient of relationship to each of these grandchildren is 1/4. We can, however, save some effort by noticing that her reproductive value under this regime of succession must be equal to the reproductive value given by Equation 1′ *plus* the extra reproductive value that she gets from the chance that she will have a legitimate grandson who inherits the duke's estate, but is not the son of her firstborn surviving son (as was required in previous calculations). A grandson is said to be in the *direct line of succession* if he is the oldest

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[10] If one of the current duke's daughters is married to a duke, then the eldest son of that daughter will inherit his father's estate and hence will not be eligible to inherit his grandfather's estate as well.

[11] Alternatively, the rules of succession could specify that the estate goes to a granddaughter if the duke has a granddaughter but no grandsons. As it turns out, for reasonable parameters, the probability that a duke has at least one granddaughter but no grandsons is very small and hence makes little difference to the calculations of reproductive values.

surviving legitimate son of the duke's firstborn surviving legitimate son. A grandson who inherits the duke's estate despite not being in the direct line of succession would have been a commoner with a reproductive value of 1 he had not succeeded to the ducal estate. Therefore his net gain in reproductive value would be $V_m - 1$. Let us denote the probability of succession by a grandson who is not in the direct line of succession by Π'. Since the coefficient of relationship of the duchess to her grandchildren is 1/4, the reproductive value that she gains from the possibility that the estate passes to a grandchild who is not in the direct line of succession is is $\frac{1}{4}\Pi'(V_m - 1)$. Therefore the reproductive value of a duchess is given by

$$V_f = \frac{1}{2}\Pi V_m + \frac{1}{2}\Pi V_f + \frac{G'}{4} + \frac{1}{4}\Pi'(V_m - 1). \tag{1''}$$

Although the duke's reproductive value is increased by the possibility that the estate may be passed to children of a younger son if his eldest son provides no heirs, he gains no reproductive value from the fact his siblings or cousins might inherit the estate if he has no grandchildren. Therefore the reproductive value of a duke continues to be determined by the equation:

$$V_m = (1 + \theta)V_f + \frac{B}{2}. \tag{2''}$$

Solving the simultaneous equations $1''$ and $2''$, one finds that

$$V_f = \frac{B(\Pi + \frac{\Pi'}{2}) + G' - \Pi'}{4(1 - \Pi) - 2\Pi\theta - \Pi'(1 + \theta)}. \tag{3''}$$

$$V_m = \frac{B(2 - \Pi) + (1 + \theta)(G' - \Pi')}{4(1 - \Pi) - 2\Pi\theta - \Pi'(1 + \theta)}. \tag{4''}$$

Expressions $3'' - 4''$ are not as simple or as beautiful as the valuations for simpler versions of the models. On the other hand, if we have empirical estimates of the parameters of B, G', Π, and Π', the reproductive values of dukes and duchesses are easily calculated from these expressions. Allowing indirect succession contributes to the reproductive value of duchesses as well as of dukes, since it increases the likelihood that a duchess will produce an heir. In our later discussion we estimate the demographic parameters that apply to the British nobility in early modern times. With these parameter values it turns out that allowing indirect inheritance increases the reproductive value of dukes and of duchesses each by about 20%.

Section II.   Demographic Parameters from Historical Sources

II.1.   Reproductive behavior of the nobility of ancient civilizations

In each of the first six great recorded civilizations studied by Betzig, powerful men mated and reproduced prodigiously. The emperors and nobles maintained large harems, to

which they had a strict monopoly of sexual access. Frequently, they also had sexual access to wives and daughters of their subordinates. Betzig (1986, 1993) describes these practices in rich, sometimes lurid, detail and finds strong evidence that noblemen valued not only sex, but fertility. Their sexual partners were almost always of prime reproductive age and were carefully shielded from impregnation by other men.[12] In all of these civilizations described by Betzig, children of the harem were very well cared for.

A similar pattern seems to have been maintained in Imperial Rome. Marriage was monogamous, but according to the writings of classical authors, Roman emperors and their courtiers were spectacularly promiscuous. (Betzig (1992a, 1992b) Ancient Roman aristocrats outside of the imperial court seem to have been less flamboyant in their sexual peccadillos, and official records of bastard offspring of the nobility are rare. But according to Betzig, the evidence from legal documents and from classical writings indicates:

> " ...that there were millions of slaves in the Roman empire...that sexual access to slave women was taken for granted by their masters and taken at risk by other men: that masters cared materially and emotionally for the slave women's children, often manumitted them, and gave some of them great wealth, high position, and a place in their family tombs." (1992a, p 343)

Like the Roman aristocrats, the nobles of medieval and early modern Europe married monogamously, but probably mated polygynously. As with the Romans, significant numbers of bastard offspring of the nobility are not to be found in legal documents (Hollingsworth (1964)) but again there is abundant evidence in contemporary accounts that aristocrats regularly had sexual encounters with large numbers of women from all social classes. (See Lawrence Stone, 1977).

Reproductive values in ancient civilizations

Betzig (1993) cites several bits of quantitative evidence on the number of concubines in ancient civilizations. She reports that in the Chinese T'ang empire (A. D. 618-907) emperors kept thousands of women, great princes kept hundreds, and members of the nobility kept 30 or more, others of the upper middle and middle classes kept progressively fewer. By Inca law, "principle persons" were given 50 or more wives, heads of provinces of one hundred thousand got 20 women, leaders of 1,000 got 15 women, administrators over 500 got 12 women, governors of 100 got 8, and petty chiefs over 50 men got 7 women. Among the Aztecs, the number of concubines were "counted by the score among the lesser and by the hundreds among the greater nobility". While there is a lack of specific numbers, the writings about the Egyptians, the Sumerians, the Assyrians and the Babylonians, indicate that in all of these societies, rich men had very large numbers of mistresses and sired

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[12]   In China, the emperor's sexual encounters were deliberately managed so as to maximize his reproductive possibilities. Records were kept of the menstrual cycles of each woman in his harem, and the date and hour of each successful copulation was recorded. Sexual encounters were arranged to occur at the time thought most favorable for conception. Betzig (1993))

correspondingly large numbers of children. Assuming rather conservatively that his concubines on average bear a nobleman one surviving child, the number of bastards produced by members of the lesser nobility in T'ang China, in the Inca empire and the Aztec empire would seem to be on the order of 50 and the number of bastards produced by the greater nobility might be of the order of 500.

For the ancient civilizations, we do not have estimates of the other parameters needed to estimate reproductive value, the probability that a nobleman would be able to pass his wealth and power to an heir, the fertility of the sisters and younger brothers of the eldest son, and so on. However, we do have reasonably reliable estimates of these parameters for the aristocratic families of medieval and early modern Britain. If the British parameters for fertility and mortality are applied to the ancient civilizations (and if it is assumed that the younger brothers of a duke who inherits his estate each have half as many illegitimate children as the duke), we can make some rough guesses of the reproductive values of the nobility in these societies. Applying the bastardy rates of these societies to equations 6 and 7 found below, we would estimate the reproductive values of minor noblemen to be about 65 times that of a commoner and of great noblemen to be about 650 times that of a commoner. The reproductive values of the women who bear their heirs, would be about half that large.

II.2. Reproductive behavior of the British nobility in the 17th through 19th centuries

Remarkably detailed records have been kept on the marriages, fertility, and mortality of the British nobility. The most useful source of information for our purposes seems to be T. H. Hollingsworth's "A Demographic Study of the British Ducal Families" (1957). Hollingsworth tabulated the vital statistics for the 1,908 individuals who were legitimate offspring of British kings, queens, dukes, and duchesses and were born during the 624 year period from 1330 to 1954. Hollingsworth calculates separate age-specific marriage rates, legitimate birth rates and mortality rates for the period from 1330-1679, 1680-1829, and 1830-1954. According to Hollingsworth, after 1700 this data becomes "almost as complete demographically as it is reasonable to desire." The estimates used here are based on the period from 1680-1829. By making a few assumptions to fill in omitted details of Hollingsworth's demographic tables, I have been able to construct estimates of almost all of the parameters that are essential to the model being considered here.[13] The only critical set of facts for which Hollingsworth 1957 paper supplies little or no information is the number of illegitimate children sired by the dukes and their sons.

Two other studies supply an impressive amount of demographic information for somewhat different populations of British nobility. In 1964, Hollingsworth published a study

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[13] These calculations were done with *Mathematica*. A *Mathematica* notebook containing these calculations is available on request.

of age specific rates of marriage, fertility and mortality for all legitimate offspring of those British peers who died between 1603 and 1939. The population of British peers consists of all members of the British House of Lords, which include dukes as well as lesser nobility—marquesses, earls, viscounts, and barons.[14] Lawrence Stone and Jeanne C. Fawtier Stone (1984) collected and analyzed a sample of families of "the landed elite" in three English counties for the period from 1540-1880.[15]

Parameters of the bare-bones model

In the bare-bones model described in equations 1-5, the only parameter that we need to know in order to determine the ratio of the reproductive value of a duke relative to that of a duchess is the probability Π that a married duke will have a legitimate son who survives to adulthood, marries and succeeds his father as duke. According to Hollingsworth, about 21% of all married dukes fathered no legitimate children. Hollingsworth's data on the size distribution of families, plus the information he gives us about the probabilities of survival to age 20 enable one to calculate the probability that a duke has no male heirs. According to my calculations based on Hollingsworth's data, this probability is about .33. About 8% of all eldest sons of ducal families who reach age 20 never marry. Therefore about 40% of married dukes did not produce a surviving son who married.[16] This means that the probability Π that a married duke and duchess have a son who survives and marries is about .6. There remains the possibility that the duke fails to pass his estate to an heir, not because of demographic failure, but because of a failure in his economic or political fortunes. Hollingsworth offers no evidence on the frequency of such failures. The Stones' study of British peers suggests that such failures were rare among the country elite. They studied all records of sales of the estates in their sample and report that "only 8 per cent of all inheritor owners of a 340-year period were forced out of their status position in the country elite by financial difficulties causing sale or status decline."(Stone and Stone p.180).

If we assume that independently of his demographic fortunes, there is an 8% probability that a duke will lose his estate, then the probability that the duke is able to produce a

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[14] This includes a total of about 28,000 people. While Hollingsworth supplies much interesting information about this population, he does not present any data on the distribution of family size, nor does he treat elder sons separately from younger sons as he did in his study of ducal families.

[15] The counties were Northamptonshire, Hertfordshire, and Northumberland. Membership in the elite, as defined by the Stones, depended on ownership of a "a country seat of a certain minimum size and aesthetic elegance." Their sample included the owners of 362 estates–a total of 2246 persons over the 340 years of the study.

[16] In their sample of country estates, Stone and Stone find that for the period from 1650-1799, the percentage of the landed elite homeowners in their sample who died without a surviving son remained close to 40%, but the percentage of *married* homeowners who died without a surviving son was only about 26%.

male successor becomes approximately .55.

I have not been able to find detailed direct evidence on the fraction of all ducal families who produce a daughter who marries a ducal heir and becomes a duchess. John Cannon (1984) observes, however, that in the period from 1640-1800 marriages of British peers were "overwhelmingly within their own social group." Computations by Cannon (1984), based on Hollingsworth's 1964 study indicate that more than 60% of the wives of peers were either daughters or close relatives of peers and more than 70% came from the aristocracy more broadly defined to include baronets and knights as well as peers. This evidence at least does not contradict the simplifying assumption made in our model that the probability that a duke and duchess produce a daughter who becomes a duchess is the same as the probability that they produce a son who becomes a duke.

Setting $\Pi = .55$, one sees from equations 3 and 4 that the reproductive value of a duke (relative to that of a commoner) is about $.8B$ and that of a duchess is about $.3B$, where B is the expected number of bastards sired by dukes. With $\Pi = .55$, the reproductive value of a duke is about 2.6 times that of a duchess.

The fertility of legitimate nonsuccessors, second marriages by dukes, and indirect inheritance

In my calculations of family size and composition based on Hollingsworth's data, the expected number of surviving legitimate younger sons who are not directly in the line of succession turns out to be about 1.1. Hollingsworth supplies quite good information on the fertility of these younger sons. My calculations based on his data indicate that the expected number of legitimate children born to a married younger brother is about 2.8. Since about 20% of surviving younger brothers never marry, the expected number of surviving legitimate offspring produced by a married younger son is about 2.3. Since the expected number of younger sons in a ducal family is about 1.1, the expected number of legitimate offspring that they produce is about 2.5.

Hollingsworth does not supply specific information on marriage rates or fertility of dukes' daughters who do not marry dukes, though there are indications that these daughters are much less fertile than those who do marry dukes. About 1/3 of a duke's married daughters marry commoners or foreigners. These daughters give birth to an average of 3.0 children, of which an average of 2.1 survive to adulthood. About 15% of a duke's daughters never marry, which means that about 18% of those daughters who do not marry dukes never marry. Assuming that unmarried daughters have no children, our estimate of the expected number of offspring of legitimate successor daughters is 82% of 2.1, which is about 1.7. Assuming that the expected number of surviving nonsuccessor daughters in a ducal family is 1.1, the expected number of grandchildren from this source is approximately 1.9. Adding the expected number of offspring of nonsuccessor daughters and sons, we have a total expected number of 4.4 legitimate children born to legitimate nonsuccessors

offspring of a duke. To find the total number G' of ducal grandchildren that the legitimate nonsuccessors produce, we would have to add the number of bastard offspring fathered by the legitimate nonsuccessor sons.

The figures on fertility that we used in estimating Π as .6, were the fertility of dukes, not of duchesses. To find the fertility of duchesses, we have to reduce this number to account for the fact that some of the dukes offspring are produced in second or later marriages after the death of the duke's first wife. Hollingsworth does not report the fertility of dukes after their first wives have died. However, Stone and Stone (Table 3.6) find that for their sample, over the period from 1650 to 1800 the number of children born to second and later wives was about 14% of the number born to first wives. Let us assumes that this percentage applies as well to the population of dukes and duchesses. This means that the probability that a duchess produces a surviving heir must be about $.6/1.14 = .52$.

The probability that a married duke produces a legitimate son who in turn produces a surviving son turns out to be about .4. The probability that a duke has at least one surviving grandson is about .72. Therefore the probability the duke has a surviving legitimate grandson although the duke's eldest son has no surviving legitimate sons is about .32. This will be used as our estimate of the parameter Π'.

II.3.   Estimating the reproductive value of male and female nobility

In the previous section, we found estimates of all of the parameters of the equations for the reproductive value of dukes and duchesses, with one important exception: the number of bastards sired by dukes and their brothers. Reliable data on the number of bastards produced by British aristocrats, unfortunately are not available.

As our earlier quotation from Lawrence Stone indicates, in the early part of the sixteenth century, illegitimate children sired by aristocrats were openly acknowledged and valued by their fathers. But, reflecting Puritan interests, social attitudes towards illegitimacy changed markedly in the late sixteenth century. In the period from 1560-1660, the activity of siring bastards, even for aristocrats, seems to have fallen into disrepute. At the end of this period, the earlier tolerance was gradually restored: Stone (1965) reports that "Presumably in deference to puritan criticism of the double standard, this casual approach to extra-marital relationships disappeared between 1560 and 1660, and in consequence we have to look elsewhere than in wills for information about the illegitimate children of Elizabethan and early Stuart noblemen." From genealogies for this period, Stone finds several examples of illegitimate births in aristocratic families, but the number of acknowledged bastards was apparently much smaller during this period than before or later.[17]

In the late seventeenth and in the eighteenth century, bastardy seems to have been restored to respectability. According to Stone (1977): "throughout the eighteenth century

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[17]   This was the case despite quite spectacular sexual promiscuity practiced in the royal courts in the late sixteenth and early seventeenth centuries.

it remained quite common in upper class circles for men of rank, position, and quality to keep a mistress or series of mistresses." It was a common pattern for these men to make arrangements with women from families of professional or merchant background to become their mistresses, in return for a fixed allowance. According to Stone (1977) "bastards appeared once more in wills in the early eighteenth century.[18] and were tolerantly accepted into the household, at least by some wives."[19]

Lacking definitive numerical estimates of the average number of illegitimate children, it is useful to express the reproductive values of British dukes and duchesses as a function of a variable B representing the expected number of bastards sired by a duke. We can then examine the implications of alternative possible numbers of bastards on these reproductive values. To make such computations, we need to make an assumption about the number of bastards sired by the duke's legitimate younger brothers. We assume that on average, each of these brothers sires half as many bastards as the duke. Given this assumption and our estimates of the other parameter values, the formulas for reproductive values are:

$$V_f = 2.6 + .7B \tag{6}$$

$$V_m = 2.9 + 1.3B \tag{7}$$

If the British dukes had no bastard offspring, then a duchess's reproductive value would be about 2.6 times as large as that of a commoner and a duke's reproductive value would be 2.9 times as large as that of a commoner. If a duke on average had 5 bastards, then the reproductive value of a duke would be about 9 times that of a commoner and the reproductive value of a duchess would be about 6 times that of a commoner. If dukes averaged 10 bastards, then the reproductive value of a duke would be about 16 times that of a commoner and the reproductive value of a duchess would be about 10 times as large as that of a commoner.

Section III.   Theory meets history to test a hypothesis

III.1.   Primogeniture and monogamy as optimizing strategies

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[18] Stone reports that the European record for fathering illegitimate children in the eighteenth century was held not by an Englishman, but by Augustus the Strong, Elector of Saxony and King of Poland who had three hundred and fifty-four acknowledged bastards. (Stone, 1977, p 532)

[19] In his will drawn up in 1721, John Duke of Buckingham, mentioned many bastards, including a son by one mistress living abroad with a tutor in Utrecht, and two girls by another being brought up by his second wife with their legitimate children... and in the 1790's there were brought up at Devonshire House and Chatham a whole collection of oddly assorted children: three were the children of the fifth Duke of Devonshire and his duchess, Georgiana, and two were the children of the the Duke and Lady Elizabeth Foster, the Duchess' most intimate friend and lifetime companion; while one child of the Duke and Charlotte Spencer and one of the Duchess and Lord Grey were brought up elsewhere. The tenth Earl of Pembroke had children by two mistresses and his bastard son, who had a successful naval career, was on the best terms with his legitimate son and heir.(Stone, 1970 pp.532-534)

The discussion so far has dealt with the genetic consequences of the practices of primogeniture and monogamous marriage. We have yet to address the question of why the actors choose to behave in the way they do within these institutions, or of why these institutions successfully maintained themselves over long periods of time in many historical civilizations.

Why primogeniture?

Why would we expect families to leave a far larger inheritance to their firstborn sons than to their other children? It is almost tautological to declare that the answer must involve "increasing returns to scale". The question is sharpened if we ask ourselves: Suppose that a nobleman wishes to allocate resources among his children in such a way as to maximize his reproductive value. Would he get more descendants by practicing primogeniture than by dividing his inheritance more equally among his descendants? If so, then over the relevant range there must be increasing returns to scale in the function that determines reproductive value of a son from his wealth. If mating as well as marriage were monogamous, it seems quite compelling that there would be decreasing returns to wealth in the production of offspring, since one crucial input, namely women, is not allowed to vary. If mating is polygynous, then it is plausible that the relation between money expenditure and number of offspring would approach constant returns to scale. But where would the increasing returns come from?

Perhaps the answer is that in an aristocratic society, "it takes money to make money." Those whose wealth reaches a certain threshold are able to command political influence so as to defend and augment their fortunes. Those of lesser but still substantial wealth are more likely to lose their wealth to marauders and political enemies. Betzig (1986) cites many examples of the way in which the wealthy and powerful in a variety of cultures obtained favorable treatment in disputes over property and women. Concerning the British nobility, of the seventeenth and eighteenth centuries Sir John Habbukuk (1979) asserts that:

> " The sale of the historic core of an estate was...more easily avoided among the great families than among the gentry. This was partly because members of the great families were better able to procure public employment... More fundamentally, the great families stood a better chance of surviving long enough for the accidents of family history–a small family or a lucrative marriage–to restore their fortunes."

Cannon (1984, Chapter 4) presents a fascinating catalog of ways that English peers in the eighteenth century used their political power to protect their estates from taxation, to gain sinecures and positions of influence for themselves and their offspring in the government, the church, and the armed forces. The British House of Lords of course, consisted exactly of the set of British peers. According to Cannon, as the influence of the House of Lords declined during the latter part of the century, the influence of the peers may have actually increased. The House of Commons came ever more strongly under the

influence of the great aristocratic families. In the late eighteenth century, about a third of the members of the House of Commons were sons, grandsons, or nephews of peers. If the offspring of baronets are included, the proportion rises to well over one half. An overwhelming majority of cabinet members were peers. During this period, more than half of the British peers held offices or 'positions of trust' in the government. There was even an 'aristocratic dole". The government even paid large annual pensions to seventeen peers "who through the vicissitudes of inheritance had become parted from a large part of their estates." (Cannon, p. 96-97) Cannon also shows that quantitatively, the major government offices–in diplomacy, the treasury, the admiralty, and the army, were dominated to a remarkable extent by the peers and their immediate descendants.

In a despotic or aristocratic society, where the extremely wealthy can make greater returns on their investments than the moderately wealthy, a nobleman is quite likely to find that the way to maximize the total earnings of his children is to leave the bulk of his inheritance to a single son. But maximizing the total wealth of his children is not necessarily the way to maximize his reproductive value, particularly if he and his sons confine their reproductive activity to a single wife. One solution to this problem is for the nobleman to augment his reproductive activities by taking on concubines, whose children he sires and supports. By this means, a nobleman could father prosperous, surviving offspring at approximately constant costs per child. Then if expected rates of return to great fortunes are sufficiently larger than expected rates of returns to small fortunes, noblemen will maximize their reproductive value by concentrating inheritance on a single son.

If primogeniture, why monogamy and why dowries?

And what of the daughters? In an egalitarian society, the expected number of descendants that a woman produces will be only slightly influenced by the family background of her marriage partner. But in a society with a wealthy hereditary aristocracy that concentrates inheritance on a single heir, there is a large genetic premium to the woman who is mother of that heir. If wealthy parents value having many descendants, then the right for their daughter to bear an heir is a commodity for which they will be willing to pay dearly. Not surprising, parents of male heirs sought to market this valuable commodity. But in order to collect a substantial price for the right to bear an heir, the family of the young heir must be able to credibly commit to its delivery. The package normally chosen for this commodity was monogamous marriage, with carefully designed (and legally enforced) pre-marital contracts that explicitly set down the lines of inheritance and the arrangement of finances between the nobleman and his wife under a wide variety of contingencies. In stratified societies with monogamous marriage and primogeniture, the price paid for one's daughter to marry an heir normally took the form of a dowry, paid by the bride's parents to the heir and his family.

III.2. Dowries and marriage settlements by the British aristocracy

The nature of marriage settlements and entails

Since at least as early as the year 1285, the English nobility signed marriage contracts in which estates were "entailed". An entail was a binding commitment by a nobleman, that restricted him from selling the entailed portion of his estate and compelling him to pass it on intact, according to a preestablished line of succession to legitimate heirs. This system evolved by the late seventeenth century into a system of firmly enforceable contracts known as *strict settlements* that remained the predominant mode of land ownership until the early twentieth century. Settlements were strikingly explicit in their protection of the rights of the nobleman's wife and her descendants under a great variety of contingencies. A brief history and a remarkably clear discussion of the workings of strict settlement is found in a short monograph *Strict Settlement–A Guide for Historians* by Barbara English and John Saville. (1983) See also the Stones (1984). The strict settlement typically involved three generations of a ducal family and gave successive life interests in the proceeds of the estate to the current landholder, his oldest legitimate son and heir, and the yet unborn oldest son of the son, the tenant *in tail*. The settlement was renegotiated once every generation, usually on the twenty-first birthday of the heir, or on the marriage of the heir.[20] The estate would be "disentailed" at the heir's twenty-first birthday, at which time lands could be sold and holdings consolidated or reorganized. A new strict settlement would typically await the heir's marriage, which normally came shortly after his coming of age.

At the time of marriage, a settlement was negotiated between the families of the bride and groom. A new entail was agreed to, whereby the heir would again restrict his rights to sell family lands and would set out the succession of heirs (including unborn contingent offspring). The heir would also commit to leave specified amounts of inheritance (*portions*) to the (as yet unborn) daughters and younger sons that his wife bears him. In addition, the bride's dowry payment was determined. The dowry became the property of her husbands estate and would not be returned to the bride in the event of his death. However, part of the negotiated settlement was an annuity payment, called the *jointure*, to which she would be entitled if she outlived her husband. Typically the jointure was a fixed annual percentage (often 10%) of the value of her dowry. Provision was made for *pin-money*, a guaranteed annual allowance for her personal expenses that she would receive so long as she and her husband survived.

On the size of dowries in the British aristocracy

Habakkuk (1955) describes the success story of Daniel Finch, 2nd Earl of Nottingham, who had eight children by his first wife and seventeen by his second wife, and who married

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[20] Settlement might also occur on the death of the head of the family, if so stipulated in his will.

three of his daughters to dukes, two to marquises, one to an earl and one to a baronet, at a total cost in marriage settlements of £52,000. Cooper (1976) reports on Dudley, 4th Lord North who, when he negotiated the marriage settlement of his eldest son in 1666, had to provide for four daughters and five sons. Only one of his daughters got a portion (£2,500) large enough to marry a leading gentry family. Two other daughters got £2,500 each and one got £1,000). The younger sons got portions ranging from £2,200 to £500. Cooper also finds examples where younger sons received larger portions than daughters.

Some systematic evidence on the average size of marriage settlements is available. In a sample of 85 marriage settlements of daughters of peers in the period from 1625-1649, Stone and Stone found the average dowry offered was £5,400. But the Stones report that of the 41 daughters in the sample who came with dowries of less than £5,000, only 5 were able to marry peers. If we exclude the offers below £5,000 that did not attract peers, we find that the average dowry offered was about £6,600. Cooper offers another estimate of the average size of marriage settlements based on a sample of 73 wills of peers. Cooper finds an average dowry of £5,050. If we assume as we did with the Stones' sample that all but 5 of the offers below £5,000 failed to attract peers,[21] then the estimated average dowry needed to attract a peer is £6,800. Evidently dowries rose quite rapidly during the latter half of the seventeenth century. On the basis of different samples, Stone (1965) reports an average settlement of £9,700 and Cooper reports an average settlement of about £9,350. When adjustments are made for the fact that the low offers are unlikely to have attracted peers for husbands, the average dowry needed to attract a peer would have been about £12,000.

Compared to the income of a commoner, these dowries constitute enormous sums of money. Average annual incomes of artisans and yeoman farmers and artisans in the seventeenth century were in the range of £40 to £100. To measure by another scale, Stone reports that the cost of building Wadham College, Oxford with its quadrangle, chapel, hall, and library was under £12,000 between 1603 and 1613.

Another interesting scale against which to measure a duchess's dowry is the value of the estate over which she becomes duchess. Great estates were rarely sold in their entirety, but historians have used accounts kept by estate-owners to estimate the annual flows of rental income that they generate. Estimates of the market value of estates can thus be constructed by capitalizing the expected cash annual income that they generate. As Stone (1965) explains, estimates of aristocratic income found in the literature vary considerably, partly because they are based on spotty sources and partly because of conceptual ambiguities over how to measure income. Stone estimated that the average annual income of peers in 1641 was about £5,000. According to Cannon, estimates of average income of peers at the

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[21] Cooper points out that larger portions were frequently given to elder daughters than to younger ones. Presumably the younger daughters would then often not be able to marry a peer.

end of the seventeenth century range from £3,200 to £8,000.[22] Thus the average dowry brought by the wife of a peer seems to have been in the range from one-and-a-half and three years of income of from her husband's estate. Christopher Clay (1968) reports that the rate of return on land was "about twenty years' purchase" and that borrowers whose credit was good could borrow money at about a 5% interest rate. Thus the market value of a duke's estate would have been about twenty years income. If the dowry that a wife brings is two years' income from the estate, then her dowry would have been in the range from 7.5% to 15% of the value of the estate.

Why were the dowries of duchesses not larger?

Although dowries of peers were enormous relative to the income of commoners, there is reason to wonder why they did not constitute a larger share of the estate than these estimates indicate–at least if one maintains the hypothesis that royal families sought to maximize their reproductive success. Our estimates of reproductive values for English male and female peers suggests that if male peers have an average of 5 illegitimate children and their younger brothers each have an average of 2.5 illegitimate children, then the reproductive value of a male peer will be about 1.5 times that of a female peer. This ratio will be higher, the greater the number of bastards a male peer fathers and the smaller the number of bastards fathered by his younger brothers. In the limit as the number of bastards fathered by the peer is made large in absolute terms and large relative to the fertility of his brothers, the ratio of the reproductive value of dukes to that of duchesses is slightly less than 3.

If the reproductive values of male peers are 1.5 times the reproductive values of female peers, one might expect that the cost of endowing a male heir with an estate should be about 1.5 times the cost of giving a daughter a sufficiently large portion for her to marry a peer. If the measured value of a peer's estate includes the amount of the peer's inheritance plus the dowry that he received at marriage, and if the peer's inheritance were 1.5 times the dowry, then it would have to be that dowries constituted about 40% of the value of ducal estates rather than the 7.5% to 15% that we have estimated. Even if the number of bastards produced by dukes were sufficient for male peers to have reproductive values 3 times as large as female peers, equality of relative costs to the ratio of reproductive values would require that dowries be about 25% of the size of estates.

The hypothesis that parents seek to allocate inheritance among their children in such a way as to maximize their own reproductive value does not necessarily imply that there should be equality of total reproductive value per dollar invested in male peers and in female peers by their parents. Economic theory predicts only that a *marginal* dollar invested in the dowry of a daughter adds as much to one's reproductive value as a *marginal* dollar

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[22]   The figure £3,200 comes from a contemporary estimate by Gregory King's in 1696 .

added to the estate of the eldest son and heir. But one can construct a plausible model equality of marginal reproductive value per dollar spent implies approximate equality of total reproductive value per dollar spent on dowries and on estates. One model that comes to mind is the following: Heirs to estates choose to marry the women who bring the highest dowries. If the cost per unit of reproductive value gained by endowing daughters sufficiently for them to marry peers is less than the cost per unit of reproductive value of leaving estates to peers, then families that had two or more daughters could achieve greater reproductive value for their money disinheriting their eldest son and endowing two or more of their daughters with sufficient funds to become duchesses. [23] [24] But if this were done widely, then at current dowries, there would be an excess supply of women wishing to marry peers, so the dowry price would rise to equilibrate the market.

One interesting possible explanation for the apparently low size of dowries is that not all of the considerations that come from the bride's family to the groom's are included in the dowry. A nobleman who marries a daughter of a powerful family may expect that in the future he will receive valuable political or military favors from his in-laws. Therefore the money paid as dowry understates the total value of payments that accompany the bride. The reason one would expect post-marital payments to flow in the direction from the bride's family to her and her husband rather is that her kinfolk have a genetic interest in any children that she produces, while the groom and his family have no reciprocal genetic interest in their in-laws. Therefore the bride's family may be willing to spend resources on their daughter's children beyond the dowry that was contracted before it was known with certainty whether the bride would succeed in producing surviving children.

III.3. The line of succession in the British aristocracy

Kin-selection and inheritance through the female line

In each generation, the line of succession for the following generation was specified as part of the marriage contract. If the current tenant was still alive on the twenty-first birthday of the tenant in tail, then at any time after this birthday a new settlement could be made. The new settlement would specify the line of succession to the estate in each of several contingencies that might occur when the current heir dies after having inherited the estate. Typically the new settlement would be made at the time of the heir's marriage, shortly after his twenty-first birthday in negotiations involving the current tenant, the heir, and the family of the bride.

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[23] Although a nobleman who has promised to leave an estate to his eldest legitimate son can not renege on that promise after the marriage settlement is signed, it would be possible at the time that the marriage settlement is signed and with the consent of both the bride's and groom's families to agree to sell land from the estate in order that larger portions could be provided for marriageable daughters.

[24] Daniel Finch, 2nd Earl of Nottingham, cited above, did not disinherit his sons, but he evidently found that marrying his daughters to peers offered good value for his money.

According to English and Saville, it was legally possible to name any person in a settlement–"only custom" kept inheritance to near relatives and "only custom" emphasized primogeniture. But this is a custom that was maintained for centuries by the great majority of the wealthy landed families, despite the fact that once a generation, the head of each family could have chosen an entirely different strategy of inheritance. Therefore it seems compelling that the choices made, must somehow have accorded with the interests of those who made them.

The new entail that is drawn up at the time of the heir's marriage is said to be *tail male* if after the current heir has inherited the estate, his successor upon his death must be the tenant's nearest relative in the male line, of the appropriate generation. An entail is said to be *tail general*, if precedence is determined by nearness of relationship, independently of sex–with daughters having precedence over nephews, and so on. Since each marriage settlements could be drawn up to reflect the preferences of the parties to the settlement, the settlements did not have to be purely *tail male* or *tail general* for all contingencies. For example, the settlement could give precedence to a nephew over a daughter, but precedence to a daughter over a cousin's son.

Stone and Stone (1984) report that the choice between settlement in *tail male* and inheritance in *tail general*, was often a difficult one for English families.

> " The English elite never fully made up its mind whether to follow the patrilineal or the cognitive principle in organizing the transmission of title and property...When it came to the critical matter of the descent of property in cases where there was no son to inherit, daughters were admitted to have strong claims to a substantial, and occasionally a major, share of the inheritance. Given a free hand, fathers were naturally likely to favour daughters over cousins in such circumstances. The long-term interest of the family, however, as expressed in legal documents such as entails and settlements demanded passage of the property more or less intact to the nearest male relative. Finally, everyone was more or less agreed that the bulk of the estate should be passed intact to a single individual, on the principle of primogeniture..."

The reproductive values of alternative choices of succession

Let us compare the reproductive values to each of the parties to a marriage settlement of *tail male* versus *tail general* inheritance under two of the more interesting interesting demographic contingencies for a family. Let contingency 1 be the case in which the heir to the estate will has no surviving sons, has at least one surviving daughter and also has at least one nephew in the male line of succession. Let contingency 2 be the case where the heir has no surviving sons, at least one surviving daughter, no nephews in the male line of succession, but a cousin in the male line of succession.

In contingency 1, under *tail general*, the heir's daughter would inherit the estate and under *tail male* the heir's brother's son would inherit the estate. The current tenant–father of the heir–would definitely prefer that the inheritance go to the heir's brother's

son, who is the tenant's grandson rather than to the heir's daughter, who is the tenant's granddaughter.[25] The tenant's coefficient of relationship to each of the possible heirs is $1/4$, so that passing the estate goes to the male adds $V_m/4$ and passing it to the female adds $V_f/4 < V_m/4$ to his reproductive value. The bride's parents on the other hand, would definitely prefer *tail general* since their coefficient of relationship to one of the heir's legitimate daughters would be $V_f/4$ while they are unrelated to the heir's brother's son. For the heir, himself, we have to consider extended reproductive value rather than simply reproductive value, since the choice between *tail general* and tail male is a choice between augmenting his own reproductive value and that of his brother's son. The heir's coefficient of relationship to his nephew is $1/4$ and his coefficient of relationship to his daughter is $1/2$. Therefore the heir will prefer that the estate goes to his daughter if $V_m/4 < V_f/2$, or equivalently $V_m < 2V_f$ and will prefer the estate to go to his nephew if the inequality is reversed.

In contingency 2, as in contingency 1, the bride's family will prefer female succession. The father of the heir has a coefficient of relationship of $1/4$ to the daughters of the heir and a coefficient of relationship of $1/8$ to the sons of his brothers. Therefore the father of the heir will have higher reproductive value under male succession than under female succession if $V_m > 2V_f$ and higher under female succession if the inequality is reversed. The heir has coefficient of relationship $1/2$ to his daughter and $1/16$ to his cousin's son. Therefore the heir will prefer female succession so long as $V_f > V_m/8$.

Predicted outcomes of bargaining.

Calculations by Lloyd Bonfield (1979) suggest that the probability that an English peer who had surviving sons would, himself, be alive at the time of his son's marriage was about $1/2$. If the peer dies before the marriage of his heir, then the heir at the time of his marriage is free to negotiate the marriage contract directly with his in-laws. If at the time of the heir's marriage, his father–the current life tenant–is still alive, then the terms of the marriage settlement are likely to reflect the reproductive interests of the heir's father, which are not identical to those of his son. English and Saville describe the situation of an heir with whose father is alive as follows:

> "The heir who was tenant in tail was, theoretically, but only theoretically, in
> a strong position when he came of age at 21. If he refused to co-operate with
> his father (or other life tenant, perhaps his uncle, grandfather, or cousin),
> the entail could not be broken, and the tenant in tail must eventually inherit
> lands that he could easily turn into a fee simple.[26] The difficulty was to
> survive in the meantime: until he inherited the estate, at a time which might

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[25] Notice that the tenant's reproductive value is just as high if the estate goes to a son of a younger son as it would have been had his eldest son produced a son.

[26] Fee simple means ownership with few strings attached.

be years away...In practice, the prospect of an immediate income, possibly with future increments...as well as the strong pressures of family tradition, persuaded the tenant in tail to join the life tenant in resettling. ”

These observations suggest that we would expect that about half of the marriage settlements made–those for which the father of the heir is alive at the time of his son's marriage–would reflect the outcome of bargaining between the father of the heir and the bride's family. The other half of the contracts would be the outcome of bargaining between the heir and the bride's family.

Making some plausible guesses about the number of illegitimate children fathered by British peers and their sons, we estimated that in the seventeenth and eighteenth centuries, V_m was about one and a half times as large as V_f. If this ratio is approximately correct, then it must be the case that when the heir bargains directly with the bride's family, both sides would favor succession by his daughter rather than by his nephew in contingency 1 or his cousin's son in contingency 2.

If the heir's father is alive at the time of the heir's marriage, then in contingency 1, he would favor inheritance by the heir's nephew rather than by the heir's daughter. In contingency 2, the heir's father would favor inheritance by the heir's daughter. Since in contingency 1, the bride's family would prefer inheritance by the heir's daughter, the question of whether the outcome of the bargain will be male inheritance or female inheritance in contingency 1 can not be answered simply from the ordinal information that we currently possess.[27] Under contingency 2, the heir's father, like the bride's parents would prefer that the estate go to the heir's daughter rather than to the heir's cousin's son.[28]

Was succession in actual marriage settlements as predicted by reproductive values?

English and Saville explain that the line of succession was decided independently by the parties to each marriage settlement rather than mandated by a legal template. Although samples of actual marriage settlements have been studied by Clay, by English and Saville, and by Stone and Stone, the Stones inform us that none of these studies has directly investigated the proportion of marriage settlements that opt for male or female inheritance in contingencies 1 and 2. Stone and Stone observe that after 1740 there was a substantial

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[27] In the language of bargaining theory, the information available so far is not sufficient for us to construct the utility possibility set. The utility possibility set is the union of the two simple utility possibility sets obtained by varying the size of dowry under the two alternative rules of succession.

[28] The conclusions of the preceding paragraph depend critically on the result that $V_m < 2V_f$, which in turn depended on the assumption that the number of illegitimate offspring produced by the peers was moderate and that the brothers of peers each produced half as many bastards as the peers. If the peers produced more bastards and the brothers produced less than we have assumed, it is possible to have V_m between 2 and 3 times as large as V_f. If this were the case, then both the tenant and the heir would prefer male succession in contingency 1 and the tenant, but not his heir would prefer male succession in contingency 2.

increase in the proportion of estates inherited by females or indirectly through females. They speculate that an improvement in the position of women in society led more landholders to "draw up the contingent remainder in their strict settlements in such a way as to give precedence to close cognitive kin, such as a sister's son, over a remote patrilineal cousin only tenuously linked by male blood some two or three generations back." (p. 119)

Although we lack direct evidence on the order of succession chosen in marriage settlements, we can test some interesting hypotheses by combining Hollingsworth's (1957) demographic statistics with data provided by Stone and Stone (1984, Table 3.8) on the numbers of inheritances of great estates by male and female children of the tenants of great estates. Stone and Stone report that in the seventeenth century, about 5% of inheritances of great estates that passed from father to child went to daughters. In the eighteenth century, this percentage increased to about 7.5%.

Using Hollingsworth's demographic statistics, I have estimated that approximately 9% of peers would be expected to have surviving daughters but no surviving sons. Since about 1/4 of all married peers had no surviving children at all, this means that of those peers who had surviving children, about 12% had daughters but no sons. Further calculations suggest that about 2/3 of the peers had surviving nephews in the male line.

These demographic statistics allow us to estimate the percentage of inheritances passing to daughters under assumptions that would be consistent with maximization of reproductive values by the parties to the marriage bargain. Let us assume that if the heir's father dies before the heir's marriage, the estate goes to the heir's daughter in both of the contingencies 1 and 2 defined above. Let us further assume that if the heir's father is alive when the heir marries, the estate goes to the heir's nephew in contingency 1 and to the heir's daughter in contingency 2. Heirs who married after the death of their fathers would leave their estates to a daughter whenever they have a surviving daughter but no surviving sons. Taking Bonfield's estimate that half of the heirs married after the death of their fathers and observing that about 12% of these heirs have a daughter but no sons, we would account for about 6% of all inheritances passing from father to daughter by this means. In the case where the father of the heir is alive at the time of the heir's marriage, the heir's daughter would inherit the estate only if the heir has no nephews in the male line. If the probability that the heir has no nephews is about 1/3, then about 2% of all inheritances would pass from father to daughter in a marriage contract negotiated by the heir's father. Thus under the hypothesis we have proposed, about 8% of all inheritances by the children of the tenant would pass to daughters.

Our estimates are quite crude and should be taken with a grain of salt. Yet it is interesting to see that the 8% predicted by the hypothesis that inheritance patterns are governed by reproductive values is higher than the 6% ratio that Stone and Stone find for the seventeenth century, but strikingly close to the 7.5% that they find for the eighteenth century.

III.4.   Were male heirs overvalued relative to their reproductive values?

We have examined evidence on the size of dowries relative to estates and on the lines of succession chosen by the nobility. In the case of dowry size, it seems quite likely that the size of estates given to eldest sons relative to the size of dowries given to daughters who marry heirs is larger than would be justified by the hypothesis of maximization of reproductive values. In the case of lines of successions, the evidence is less compelling. The fragmentary evidence examined here suggests that rough consistency with reproductive values, but is consistent with at least a slight tendency for marriage contracts to specify male inheritance in cases where the genetic interests of both sides to the contract would be better served by female inheritance.

One reason that has been suggested for a bias toward male inheritance is that a preservation of the family name may have become a fetish, at least partially replacing the desire for descendants. Stone and Stone argue that preservation of the family name and maintaining the connection between the name, the ancestral lands, and one's descendants was a deeply ingrained objective of the English aristocrats:

> "Whatever dispositions of property were made, the one central objective, which was never lost sight of, was to preserve the link between the house, the estates to support it financially, and the family name. The contemporary word for a country house was a 'seat'... Thomas Fuller summed up the ideal in 1662 when he wrote 'many families, time out of mind, have been certainly fixed in eminent seats in their respective counties, where the ashes of their ancestors sleep in quiet and their names are known with honor'."

Stone and Stone maintain that the English placed stronger emphasis on patrilineal than matrilineal descent as evidenced by, or perhaps because of, "the English custom of obliterating the wife's maiden name at marriage," a custom not shared by Scots, the French, or the Spanish. The Stones quote a contemporary handbook on England by Edward Chamberlayn, *Angliae Notitia* (1700).

> "The woman upon marriage loseth not only the power over her person and her will and the property of her goods, but her very name; for ever after she useth her husband's surname, and her own is wholly laid aside; which is not observed in France and in other countries where the wife subscribes herself by her paternal name."

If the English valued the preservation of the family name as a goal above and beyond its consequences for reproductive value, then we would expect a nobleman to discount the reproductive value of a daughter who marries a nobleman and loses her surname relative to that of a son who carries the family name and maintains the connection between name, family and estate.

While a daughter who marries a nobleman must inevitably have lost her surname, aristocratic families were able to find a quite satisfactory solution for the case of and heiress who inherits her father's estate and who marries a man who does not himself inherit an estate. The husband could adopt his wife's name rather than the other way

around. According to Stone and Stone, this solution was commonly practiced in the eighteenth century, with the name change being mandated by the will of the heiress's father. Surname changes were not commonly practiced in the seventeenth century. In the seventeenth century, when an heiress married, she would adopt her husband's surname, but her eldest son and heir would take the heiress's surname as his Christian name. By this practice, the link between the ancestral estate and the family name was at least temporarily maintained. However, this method was not entirely reliable because the name was likely to be abandoned in later generations, and might even be lost in the first generation if the eldest son died before reaching maturity. A third solution, that seems to have been adopted when an heiress married a husband from a relatively powerful family was hyphenation of the surnames of the heiress and her husband.[29] Perhaps acceptance of the custom of name changes and hyphenated names in the eighteenth century helped to overcome an earlier tendency of noblemen to pass their estates to distant male heirs even when it was not in their genetic interest to do so.

Section IV. Summary and Remarks

We have constructed a formal model of primogeniture in a simple stratified society, introduced a genetically-based definition of reproductive value for the participants in this society and worked out the mathematical relationship of reproductive success to demographic parameters. Using historical data, we were able to construct crude estimates of these demographic parameters for some ancient societies and for early modern Britain.

In an environment where there are strong increasing returns to wealth–particularly in a society where the accumulation and retention of wealth depends on military strength or on influence in the political and legal system–there can be a genetic advantage to endowing a single son with a very large inheritance rather than dividing inheritance in an equalitarian way among one's offspring . Because of his great wealth and influence, a single heir is be able to sire an extremely large number of children by many women. In contrast, even a wealthy female is biologically constrained to bear only a relatively small number of children. The way in which a female can achieve the greatest genetic representation in future generations is to be mother of a line of future male heirs. Parents of female offspring who wished to maximize their reproductive value would therefore be willing to pay a large amount to have their daughter married to an heir of a great estate. This willingness to pay should be translated into large dowries. These facts seem to be consistent with what is known about ancient civilizations and about early modern Britain.

The abundance of historical information about the British aristocracy in the seven-

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[29] This practice if carried on over multiple generations could produce multiple hyphenations, with surnames lined up like boxcars–a consequence which occasionally invites ridicule from the irreverent. Stone and Stone cite such examples as Burdett-Coutts-Barlett-Couts, Howell-Thurlow-Cumming-Bruce, and an admiral of the Royal Navy in the 1930's who carried the magnificent appellation, Reginald Aylworth Ranfurly Plunkett-Ernle-Erle-Drax.

teenth and eighteenth centuries allows us to make some sharper tests of the hypothesis of reproductive value maximization. For example, the theory of reproductive value maximization has implications for the size of dowries relative to the size of estates and also for the lines of succession chosen in marriage settlements. The evidence that we have been able to gather suggests that in seventeenth and eighteenth century England, dowries may have been smaller than the theory predicts. On the other hand, the data we have about the choice of lines of succession appears to be remarkably consistent with this hypothesis.

The hypothesis of reproductive value maximization does not receive unambiguous support from the tests made here. Certainly it would be interesting to test alternative hypotheses against this historical data and to test this and other hypotheses against historical data for other societies. Even if this hypothesis is ultimately rejected for more successful hypotheses, it performs admirably as an organizing principle that focuses attention on the economic connections between sexual behavior, marriage, inheritance, and the workings of a class system. A hypothesis that helps economists to read history with pleasure and curiosity cannot be entirely without merit.

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