A Social Computing-Based Analysis on Monogamous Marriage Puzzle of Human

Ning Cai, Chen Diao, and Bo-Han Yan

Abstract—Most of the mammal species hold polygynous mating systems. The majority of the marriage systems of mankind were also polygynous over civilized history; however, socially imposed monogamy gradually prevails throughout the world. This is difficult to understand because those mostly influential in society are themselves benefitted from polygyny. Actually, the puzzle of monogamous marriage could be explained by a simple mechanism, which lies in the sexual selection dynamics of civilized human societies, driven by wealth redistribution. The discussions in this paper are mainly based on the approach of social computing, with a combination of both experimental and analytical analysis.

Index Terms—Marriage systems, monogamy, polygyny, social computing.

I. INTRODUCTION

It is estimated that up to 90% mammal species have polygynous mating systems [1], including human, in which one male lives and mates with multiple females, whereas each female only mates with a single male. This is evidently advantageous for facilitating evolution by effective sexual selection.

In comparison with most of the other mammals, where generally any species possesses a constant unitary mating system, extensive complexity is manifested in human. Nearly all typical modes exist in anthropological records, e.g., monogamy, polygyny, polyandry, and promiscuity. Nonetheless, polygyny is still dominant throughout civilizations [2], which also conforms to certain biological signs such as the moderate sexual dimorphism in body size [3].

Despite the above facts, during recent centuries, socially imposed monogamy which is regulated both by laws and ethics gradually prevails all over the world. The cause of such a phenomenon seems somewhat abstruse, mainly because those who are most influential in establishing laws and shaping norms are exactly the same stratum being mostly benefitted from polygyny [4]–[6]. It is difficult to understand why these people voluntarily abandon the privilege of holding more than one wife. Thus, it is called a puzzle [4].

For the drive of transition from polygyny to socially imposed monogamy, there already exists plenty of discussions in the literature (see [4]–[10] and the references therein). As one mainstream consideration, the monogamous marriage is often regarded to result from progressive social evolution driven by intergroup competitions. Such a mechanism is usually called cultural group selection [11]. According to this mechanism, competition among communities pushes them to voluntarily adopt those norms which are helpful for the communities to surpass others. One thought is that imposing monogamous marriage suppresses intrasexual conflict through shrinking the pool of low-status unmarried men who are usually tending to be much risk-oriented [12], with supporting data that crime rate may be related to the sex ratio straightforwardly [13]. Monogamy is also closely bonded with the political egalitarianism and the level of human rights at all patterns of government [14], with statistical linkage lying between normative monogamy and democratic institutions being able to be observed in anthropological records [15]. Another new hypothesis by Bauch and McElreath [16] speculates that monogamy surpasses polygyny primarily in restraining the negative effects of sexually transmitted bacterial infections. On the other hand, a typical noncultural consideration is an inclusive fitness [9]. Recently, Fye [17] concerned the issue from a social-psychological perspective, who collected evidence via interviews which supports the idea that monogamy is maintained by consistent efforts in several protective factors. An agent-based behavioral model was built [18] to analyze the comprehensive interactions among several driving factors for the monogamous mating activities of mammals, these factors including female dispersion, adult sex ratio, and mate guarding. This should be a very interesting and notable work in the ecological area. Parallel to our research, Ross et al. [19] extended the conventional polygyny threshold model into a dual one, which could yield an equilibrium out
of a fitness maximization; Theuer and Berec [20] addressed evaluating the effect of sexually transmitted infections by constructing dynamical models.

The existing discussions are theoretically reasonable and enlightening; however, it is difficult to have any theory being always consistent with reality. For instance, consider the hypothesis of Bauch and McElreath [16]. First, although agriculture has developed for thousands of years, socially imposed monogamy reigned over the world only during the very recent centuries. For instance, polygyny was legal before 1880 in Japan, 1953 in China, 1955 in India, and 1963 in Nepal [21]. Records can hardly be found to show any sign of the correlation between population and sexually transmitted infections in these Asian countries. Second, the mating system is different from the pair bond marriage system. Even if the monogamous marriage system is validly implemented, sexually transmitted infections can still spread via a hidden dissimilar mating network, e.g., prostitution. Hence, this problem still deserves further exploration and clarification.

In this paper, we propose a novel hypothesis, which is a mechanism to explain the monogamous marriage puzzle. We speculate that the de facto monogamy may not be the result of voluntary and rational choice of any group of people; instead, it should be naturally yielded from the sexual selection dynamics of mankind in civilized societies. The key to the mechanism lies in the redistribution of wealth.

The discussions are mainly based on social computing, with a combination of both empirical and analytical analysis, where the approach is rooted within the methodological framework on parallel systems [22]–[23]. The laws of social phenomena are investigated by building and observing the behaviors of simulation systems, which are particularly advantageous in scenarios facing the loss of historical data. Typical parallel social systems [18]–[20], [22]–[25] are usually agent-based and networked, with certain analytical properties potentially acquirable via relevant theories in systems science, e.g., swarm stability [26]–[28], network controllability [29]–[30], and information spread dynamics [31]. It is worth noting that a most distinct feature is that any parallel model stands independently and can itself be deemed as a living instance, being a feasible alternative, implementation, reference, or compensation for the corresponding systems in the real world.

Compared with relevant studies, the main advantages of the work presented here are threefold: 1) a straightforward hypothesis for the cause of socially imposed monogamy is testified via social computing; 2) the effect of sexually transmitted diseases (STD) is analyzed based on an analytical model being simultaneously compatible with the marriage and mating systems; and 3) the overall study is conducted from a viewpoint of systems dynamics and can be easily reproduced and extended. It is believable that the current research can provide meaningful theoretical hints and enrich the relevant interdisciplinary literature, both for the issue and for the methodology.

The rest of this paper is organized as follows. Section II elaborates the mechanism of the monogamous tendency based on a simulation model. Section III particularly discusses the effect of the marriage system on the overall wealth gap in society. Section IV addresses the Matthew effect. The impact of STD on the population is analyzed under different marriage systems in Section V. Finally, Section VI presents the concluding remarks.

II. SIMPLE MECHANISM TO EXPLAIN THE PUZZLE

As society shifted into patriarchal, it must adopt either polygamous or monogamous marriage system; meanwhile, it develops a set of rigorous norms to compel women to keep their chastity. This is because a father needs to guarantee the authenticity of his parenthood, in order that his property can be inherited by the genuine children of his own.

The spouse selection in a civilized society is generally economy driven. Suppose that at an initial stage, the marriage system is polygamous. Polygyny is dependent on the intensity of the overall wealth gap in society. Intensive polygyny should be rooted in an intensive status of the wealth gap. Often, a prerequisite for someone to keep more wives is that he is richer than average. However, having more wives means having more children, and accordingly, the inheritance of his property would be diluted since it has to be divided into more number of parcels. Such a mechanism could naturally suppress the wealth gap and the difference of wife numbers throughout a society, correspondingly.

Polygyny can effectively limit the accumulation of property through generations and suppress the overall status of the wealth gap. This is a spontaneous mechanism of balance, with dynamic negative feedback. A man who keeps multiple wives enjoys the welfare of being advantageous in spreading his genes, but he must also bear the price of diluting property by inheritance. In this way, the advantage of his descendants for competition in sexual selection is weakened, as compared with himself.

The mechanism restraining the intensity of polygyny is empirically testified by a very simple simulation model. One will see that the variance of wife number keeps approximating zero, indicating almost de facto monogamy.

The model is discrete-timed, with each iteration representing a generation of people. The procedure of the model can be divided into several sections. The first section is wealth distribution. The initial wealth distribution among men is Gaussian. Assume that initially, the overall wealth gap is relatively higher. This might be due to war just occurred or some other event that could arouse the redistribution of social wealth. The serious wealth gap is expressed by randomly selecting 10% of men to hold additional wealth, with the mathematical expectation many times greater than ordinary.

The second section is marriage, which is the most important section. The number of wives of a man is determined by the wealth he holds. Such a relation between the quantity of wives and the amount of wealth relative to others is depicted by a function in our model, which has several principles.

1) The function is increasing.
2) The function will tend to some quasi-saturation if the amount of wealth is sufficiently great. The reason is due to both the bounded demand and the limited resource.
3) The slope of the function is not only less than 1 in general but also decreasing. This analogously accords
4) The value of the function is 1 as the amount of wealth equals the average.

According to the above principles, we set the relation function as the following form:

\[ y = \lambda \tanh(x/\mu) - \lambda \tanh(1/\mu) + 1 \tag{1} \]

where \( \tanh(x) \) is the hyperbolic tangent function, \( x \in \mathbb{R} \) is the ratio of the amount of wealth to the average, \( y \in \mathbb{R}^+ \) is the mathematical expectation of wife quantity, and \( \lambda, \mu \in \mathbb{R}^+ \) are the parameters shaping the curve. Fig. 1 illustrates a sample of such a relation function.

The program randomly chooses an unmarried man and assigns him a number of wives from the set of unmarried women in the same generation. For this purpose, first, function (1) is computed. Next, the idiosyncratic effect due to other factors, except wealth is reflected by additionally multiplying a noise, which is a Gaussian random number with the mathematical expectation being 1. Finally, the rounded result is the quantity of his wives. After this, the program randomly chooses another unmarried man to assign him wives, similarly following the rules above. Such a process is repeated until all the unmarried women are assigned out.

The third section is reproduction. It is rational to set the average fertility of women as three or four, representing the quantity of children that could grow up. There are different cases in different families. Thus, for each woman, the actual quantity should be yielded by multiplying an additional noise, which is a Gaussian random number with the mathematical expectation being 1.

The fourth section is the inheritance. Since it is a patriarchal society, the wealth of a father would be evenly divided and inherited by his sons. This is consistent with the very situation in ancient China [33]. In addition, each of the sons will have a career and his life savings by his own should be added, which is also modeled as a Gaussian random number.

For the beginning generation, there are equal numbers of men and women. Then the new generations are iteratively reproduced, following the same procedure described above.

We conducted experiments based on the model and observed the results. The variance of the wife quantities derived via the following formula:

\[ \frac{\sum_{i=1}^{N_m} (q_i - 1)^2}{N_m - 1} \tag{2} \]

is taken as the index indicating the intensity of polygyny in the overall society, since the mean of wife quantities is always 1. Note that in (2), \( N_m \) denotes the population of men and \( q_i \) denotes the wife quantity of the \( i \)th man. The greater this variance, the higher level of polygyny, or in other word, the lower level of monogamy happens.

According to the experimental results, a primary conclusion is that in the steady state after the first few generations, the intensity of polygyny keeps very low, with the variance being close to zero. An example is illustrated in Fig. 2, which also manifests an interesting phenomenon in our experiments that ultrahigh level of monogamy usually occurs in the generation being subsequent to any generation bearing very serious wealth gap. For more intuitive perceptions, four typical fragments of wife quantities in different generations are extracted from experimental results and listed in Table I, each with 30 successive samples.

From a systems dynamics point of view, a certain incident like war, famine, or plague that may arouse drastic wealth redistribution and lead to serious wealth gap can be regarded as a perturbation to a steady state with a low level of polygyny. One sees that the overall system is quite robust to such perturbations.
III. EFFECT TO WEALTH GAP

The fact that polygyny contributes to suppress the overall wealth gap in society can also be clearly verified from experimental observations.

Fig. 3 illustrates a comparison of overall wealth gaps between polygynous and monogamous societies under the current model. Here the intensity of the wealth gap is measured by the ratio of the standard deviation to average wealth, being expressed as

$$\sqrt{\frac{\sum_{i=1}^{N_m} (\zeta_i - \zeta_a)^2}{N_m - 1}} / \zeta_a$$  \hspace{1cm} (3)

where $\zeta_i$ is the amount of wealth held by the $i$th man and $\zeta_a$ is the average wealth over the society.

One can see that the intensity of wealth gap generally keeps very low and relatively stationary in a polygynous society; whereas, in contrast, it is significantly higher in a society with imposed monogamy. After generations, the level of difference declines. This may be attributed to the natural tendency of de facto monogamy.

By the end of the section, it is worth noting that the observation here could also act as a partial explanation to the truth that the absolute wealth gap nowadays is generally greater than history [4], [34].

IV. INFLUENCE OF MATTHEW EFFECT

The Matthew effect, sometimes summarized as an adage “the rich get richer,” can often be observed by the cumulative advantage of economic capital [34]. This section deals with the possibly indirect influence of the Matthew effect to the marriage mode.

Suppose the expectation of fortune earned by a man is correlated with the amount he inherited. This can be modeled by multiplying the earned fortune by a coefficient, which is a function of the inheritance. According to the Matthew effect, it is natural to take an exponential function

$$y = \eta^x$$  \hspace{1cm} (4)

where $x \in R^+$ is the ratio of the amount of inheritance to the average, $y \geq 1$ is the resulted multiplier, and $\eta \geq 1$ is the parameter shaping the curve.

If $\eta = 1$, then $y \equiv 1$ and there is no Matthew effect; otherwise, a greater value of $\eta$ would imply a more intensive Matthew effect. A comparison of different shape of curves is illustrated in Fig. 4.

Let $\eta = 1.2$. The corresponding experimental result is shown in Fig. 5. One can see that the variance of wife quantities may still keep very low in the steady state, even under the Matthew effect.

A phenomenon can be noticed in both Figs. 2 and 5 that extreme low variance happens after ultrahigh level of variance. This implicates both a strong mechanism to naturally restrain high variance and a very small probability for the ultrahigh level of variance to appear.

Admittedly, the Matthew effect can restrain the tendency of monogamy. Fig. 6 illustrates the relation between the value of $\eta$ and the average variance of ten successive generations excluding the first. It manifests that the polygyny level increases with the higher impact of the Matthew effect.

V. EFFECT OF SEXUALLY TRANSMITTED DISEASES

Recently, Bauch and McElreath [16] proposed a novel hypothesis. Based on an empirical model, they conjecture that as the scale of the community kept on growing after the origin of agriculture, the impact of STD on the overall fertility of the polygamists became serious; and thereby the monogamists finally dominated in population.
Actually, a simple analytical analysis can be conducted to help validating and clarifying the hypothesis of Bauch and McElreath.

Suppose that the total population of the $k$th generation is $\zeta(k)$, with the women/men population being $\zeta(k)/2$; the baseline birth rate of a woman is denoted by $\alpha$, which is the number of children in her lifetime and can be affected by many factors expressed as multiplicative coefficients; the probability of a married woman to be infected by STD from some source outside of family is $\beta$, with the corresponding probability of a man being $\bar{\beta}$; the probability of sterility for an infected woman is $\gamma$; and the average count of wives in a family is $q$.

STD restrains the increase in population. It can be analytically explained whether or not this effect is intensified by polygyny.

For simplicity, assume that a man and all his wives will eventually get infected if any one of them is initially infected by STD and becomes infectious.

Consider the factor attributed to an initially infected husband. An expected birth rate of any woman under this factor is

$$a(1 - \bar{\beta}) + a(1 - \gamma)\bar{\beta} = a(1 - \bar{\beta}\gamma)$$  \hspace{1cm} (5)

where $a$ is the baseline birth rate excluding the effect of the current factor. This is independent of the count of wives.

Now consider the factor attributed to an initially infected wife. The expected birth rate of any woman under this factor becomes

$$a(1 - \beta)^q + a(1 - \gamma)[1 - (1 - \beta)^q] = a[1 + (1 - \beta)^q - 1]\gamma$$  \hspace{1cm} (6)

where $(1 - \beta)^q$ is the probability that none of the wives get infected. The value of (6) is negatively correlated with $q$. Suppose that $\beta = 0.04$ and $\gamma = 0.2$. The relation between the coefficient $1 + [(1 - \beta)^q - 1]\gamma$ and $q$ is illustrated in Fig. 7.

Under the factor of an initially infected wife, the population dynamics are depicted by the following equations:

$$\zeta(k + 1) = \frac{a}{2} [1 + [(1 - \beta)^q - 1]\gamma] \zeta(k) \quad (k = 1, 2, 3, \ldots)$$  \hspace{1cm} (7)

The population is an exponential function of time, with the initial difference being continuously amplified. In this way, the population of monogamous community tends to preponderate gradually. Fig. 8 manifests the ratio of monogamous to polygamous population, that is,

$$\left(\frac{1 - \beta\gamma}{1 + [(1 - \beta)^q - 1]\gamma}\right)^{k-1}$$  \hspace{1cm} (8)

over generations, where $q = 8, \beta = 0.04, \gamma = 0.2$, and $\gamma = 0.4$, respectively.

Actually, even the setting of $\gamma = 0.2$ reflects a rather high level of STD caused sterility. From Fig. 8, one can see that although due to STD, the population of the monogamous community is superior to polygynous, the significance of such an effect may still be comparatively minor in reality.

The most likely cause for a family member to be infected by external STD source is extramarital sex. In any human society, the actual mating system is not always consistent with the marriage system. There exist hidden extramarital relationships such as prostitution. The mechanism analyzed here is compatible with this fact.
VI. CONCLUSION

This paper concentrates on the monogamous marriage puzzle of mankind. A simple hypothesis is presented, which is based on an economic perspective. According to the hypothesis, the men who possess multiple wives are confronted with an intensive dilution of their wealth via heritage distribution because they tend to have more children than average people. As a result, the sons are usually less rich than their father and thereby it is difficult for them to keep the same number of wives. Simulations on an experimental model clearly manifest consistency with this hypothesis. In the steady state, a very low level of the variance of wife quantity is observable, indicating a de facto monogamy.

Due to the mechanism summarized above, the de facto monogamy is a natural tendency for mankind rather than the rational decision of any group of people. Probably, the overall set of moralities, sentiments, or even laws that have been jointly molding the monogamous pattern might just be the byproducts generated from an adaptation of society to the existing de facto monogamy.

The simulations also implicate that polygyny effectively suppresses the overall wealth gap in society. This could partially explain why the situation of the wealth gap in modern societies is often more serious than history.

It is worth mentioning that the mechanism here is merely a hypothesis. In fact, the monogamous marriage puzzle should still be comprehensively attributed to multiple causes, with the mechanism introduced here possibly being one of the primary factors, so long as it is validated by more evidence.

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