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Health Economics of Genetic Distance

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Abstract

In this note, I address the trade-off between children's health and parental preference toward similarity with children. In my model, better-off individuals mate genetically close partners and then use wealth to treat their children's health problems, caused by inbreeding depression. As a result, the relationship between parental wealth and children's health includes decreasing portions. Siblings health inequality is also non-monotonically related to parental wealth, if parents discriminate in favor of more similar children.

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1 Introduction

There is an evolutionary paradox in the parental feelings of intrigue, excitement, and pride of similarity with children, because they contradict the "clear and unambiguous cultural universal" (Parker 1996) of avoidance of incest. The positive emotions can be rationalized by the evolutionary desire to witness the expression of one's genome in her offspring. However, one lowers the chances of similarity with her future children by mating a genetically remote partner. Examples from ancient Egypt and Persia (Berkowitz 2012) and later Spanish Habsburgs (Alvarez et al. 2009) show how attempts to keep the blood "pure" lead to inbreeding.

Genetic distance between partners is a continuum, on which incestuous marriage is the lower bound. Zoroastrian tradition explains incestuous marriage in Persia by "desire to preserve the purity of the race, to increase the compatibility of husband and wife, and to increase affection for children, which would be felt in redoubled measure for offspring so entirely of the same family" (Denkard 3.82 in De Menasce 1973). Remarkably, this quote does not mention direct economic incentives, such as saving on expenses of dowry or maintenance of family property. Shaw (1992) similarly argues with respect to Roman Egypt that monetary and strategic considerations are inferior to the preference-related explanations of non-royal incestuous marriage.

Examples of incestuous marriage are rare, but there is no consensus on the origins of its avoidance. Theories vary from Freud hypothesis that incest taboo is an external restriction on the natural sexual attraction to close relatives to the opposite Westermack hypothesis that the protective mechanism against incest is sexual disinterest in those with whom the individual shared her early childhood. An alternative Lévi-Strauss hypothesis suggests that marriage is a social alliance and benefits when partners come from different families. Empirical evidence is mixed (Bereczkei et al. 2004, Lieberman et al. 2003, Shepher 1983, Wolf & Huang 1980) but does not support biosocial channels, such as olfactory recognition of a kin (Schneider & Hendrix 2000).

The question in the present paper is what should be the relationship between wealth and genetic distance between partners. I argue that preference for similarity with offspring has a non-trivial economic effect. In particular, the average children's health and siblings health inequality may follow a complex relationship, which includes both increasing and decreasing portions, with parental wealth.

This paper makes two contributions. First, it links the macroeconomic literature on the relationship between genetic diversity and development (Ashraf & Galor 2013) to family economics. Second, it adds to the big literature that follows the discussion in Becker(1973, 1974) on positive and negative assortative matching in the marriage market. The present paper is the first one, to the best of my knowledge, to argue that positive assortative matching across genome may be related to the preference toward similarity with children, while negative assortative matching may be related to the preference toward children's health.

From empirical perspective, the only existing systematic data that is relevant in the context of incestuous marriage in general population are the census returns from Roman Egypt (Bagnall & Frier 2006), a province where marriage between brothers and sisters was practiced. These data are invaluable remnants from two centuries of censuses, but they lack the statistical quality needed for regression analysis and causal inference (Scheidel 2001). Yet they show stylized facts that agree with the hypothesis proposed in the present paper. In particular, the census returns indicate that marriage between brothers and sisters was common in Roman Egypt but especially in its urban areas. Meanwhile, life expectancy was higher in the rural areas (Bagnall & Frier 2006). Therefore, the census returns are in agreement with the negative correlation between prevalence of incestuous marriage and health.

2 Theory

Informally, the story is as follows. Parents obtain utility from their children's health, but marginal utility from a more similar child is higher than from a less similar one. Genetic distance between parents is inversely related to the probability of each child to be similar to each of the parents but positively related to the children's expected health.

This framework generates a negative effect of wealth on the genetic distance between partners. One can have more similar to him but less healthy children by mating a genetically close partner, but then use wealth to compensate for their poor health. For instance, Spanish Habsburgs practiced inbreeding, but could provide their children with the best treatment available in their time. This is also true for dynasties related to each other through complex schemes of intermarriage.

Furthermore, discrimination may take place if multiple children are born and the partners are unequal. For example, one of the partners may control the health care expenditures. Thus, one can mate a genetically remote partner, decreasing the expected similarity with his children, but then discriminate in favor of the more similar children, enhancing their health at the expense of the less similar children.

Finally, one should also take into account the pre-industrial low-density settlement. Spatial correlation of genome implies costs on mating a genetically remote partner. For example, sufficient wealth may allow to mate a slave captured in a remote country. For those with low resources, a genetically long-distance partnership may be impossible. This assumption implies an opposite, positive effect of wealth on genetic distance between partners.

The two effects combined induce a complex non-monotonic pattern. Generally, children's health is positively related to parental wealth, because health services and necessary for health food may be purchased. However, those with low and high levels of wealth mate genetically close partners, have similar but (relatively to wealth) unhealthy children and do not discriminate.[1] Meanwhile, individuals with intermediate wealth mate genetically remote partners, have by-average relatively healthy children but discriminate between them. In what following, I formally analyze the one-child and the two-children cases.

2.1 One child

The case of one child abstracts from discrimination. For conciseness of exposition, let us assume that only one partner has wealth and she also controls it after marriage. She can mate a genetically close or remote partner and, in both cases, the partnership generates[2] a child c, from whom she obtains utility

$$u(c) = \alpha(similarity)ln(h) \tag{1}$$

where h is the child's health and α depends on the child's similarity to her, such that $\alpha(similar) = 1$ and $\alpha(dissimilar) < 1$. If the partners are genetically close, the child is similar to each of them, but if the partners are genetically remote, the expected α is smaller than one.[3] Let us denote it with $\underline{\alpha}$.

Furthermore, the child's health is

$$h = \varepsilon\delta \tag{2}$$

where ε is the parental wealth and $\delta \in \{\underline{\delta}, \bar{\delta}\}$ is the genetic distance.

The wealth holder chooses a partner that maximizes his expected utility from the future child. The solution of the maximization problem $max_{\delta \in \{\underline{\delta}, \bar{\delta}\}} E(u(c)|\delta)$ leads to a cutoff $\varepsilon'' = (\frac{\bar{\delta}\underline{\alpha}}{\underline{\delta}})^{\frac{1}{1-\underline{\alpha}}}$, such that wealth holders with $\varepsilon < \varepsilon''$ mate genetically remote partners, while those with $\varepsilon > \varepsilon''$ mate close ones. As a result, the child's health *decreases* at $\varepsilon = \varepsilon''$ from $\bar{\delta}\varepsilon''$ to $\underline{\delta}\varepsilon''$.

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[1] One can exercise also other forms of health discrimination, such as infanticide and poor treatment of female or high-parity offspring.

[2] In multi-generational inbreeding, the number of children is also affected, because one of the health effects of inbreeding is on fecundity. However, in the present context, the level of fertility can be modeled as the level of infant mortality, and, thus, is captured by the expected child's health.

[3] For instance, if the probability of a child in a genetically remote partnership to be similar to the wealth holder is 0.5, the expected α is $0.5(1 + \alpha(dissimilar))$.

2.2 Two children

Now let the partnership generate two children, from whom the wealth holder obtains Cobb-Douglas utility

$$u(c_1, c_2) = \alpha(similarity_1)ln(h_1) + \alpha(similarity_2)ln(h_2) \tag{3}$$

where h_i is the child i's health. If the partners are genetically close, both children are similar to the wealth holder. Without loss of generality, in case of remote partners, only the first child is similar to the wealth holder. The child i's health is

$$h_i = e_i\delta \tag{4}$$

where $e_1 + e_2 \leq \varepsilon$.

The wealth holder solves the maximization problem $max_{\delta\in\{\underline{\delta},\bar{\delta}\}}E(u(c_1, c_2)|\delta)$. The solution is that in case of genetically close partners, $e_1 = e_2 = \frac{\varepsilon}{2}$. In case of remote partners, $e_1 = \frac{\varepsilon}{1+\alpha}$ and $e_2 = \frac{\alpha\varepsilon}{1+\alpha}$. The cutoff is $\varepsilon'' = (\frac{4\bar{\delta}^{1+\alpha}\alpha^\alpha}{(1+\alpha)^{1+\alpha}\underline{\delta}^2})^{\frac{1}{1-\alpha}}$, where $\alpha = \alpha(dissimilar)$. Individuals with $\varepsilon < \varepsilon''$ mate remote partners, while those with $\varepsilon > \varepsilon''$ mate close ones. To summarize,

Proposition 1.

(a) The average level of children's health and h_1 drop at ε''.

(b) h_2 drops at ε'' if $\frac{\bar{\delta}}{\underline{\delta}} > \frac{1+\alpha}{2\alpha}$ and rises otherwise.

(c) The siblings health gap $\frac{h_2}{h_1}$ converges at ε'' from α to one.

Proof. (a)+(b): The maximization problem $max_{\delta\in\{\underline{\delta},\bar{\delta}\}}E(u(c_1, c_2)|\delta)$ implies that at ε'' the mating shifts from genetically remote to genetically close partnership. As a result, for $\varepsilon > \varepsilon''$, each child's health (and the average) is $h_i = \frac{\underline{\delta}\varepsilon}{2}$. For $\varepsilon < \varepsilon''$, $h_1 = \frac{\bar{\delta}\varepsilon}{1+\alpha}$ (which is higher than $\frac{\underline{\delta}\varepsilon}{2}$ because $\alpha < 1$ and $\underline{\delta} < \bar{\delta}$), and $h_2 = \frac{\alpha\bar{\delta}\varepsilon}{1+\alpha}$, which is lower than $\frac{\underline{\delta}\varepsilon}{2}$ iff $\frac{\bar{\delta}}{\underline{\delta}} > \frac{1+\alpha}{2\alpha}$. The average health is $\frac{\bar{\delta}\varepsilon}{2}$, which is higher than $\frac{\underline{\delta}\varepsilon}{2}$. (c): It follows from the proof of (a) and (b) that $\frac{h_2}{h_1} = 1$ for $\varepsilon > \varepsilon''$ and $\frac{h_2}{h_1} = \alpha < 1$ for $\varepsilon < \varepsilon''$. QED.

2.3 Spatial correlation of genome

Assume further that genome is spatially correlated. Individuals with a low level of wealth ($\varepsilon < \varepsilon'$) cannot mate a genetically remote partner, because they cannot afford the necessary travelling. Furthermore,

Proposition 2. Assume that $\varepsilon' < \varepsilon''$ and denote $\tilde{h}_i = \frac{h_i}{\varepsilon}$. Then:

(a) Sibling-average $\tilde{h}$ and $\tilde{h}_1$ follow an inverse U-shape as a function of ε.

(b) $\tilde{h}_2$ follows an inverse U-shape as a function of ε if $\frac{\bar{\delta}}{\underline{\delta}} > \frac{1+\alpha}{2\alpha}$ and it follows a U-shape otherwise.

(c) $\frac{\tilde{h}_2}{\tilde{h}_1}$ follows a U-shape as a function of ε.

Proof. (a)+(b): From the assumption that genetically remote partnership is impossible when $\varepsilon < \varepsilon'$ and from Proposition 1, it follows that for $\varepsilon < \varepsilon'$ and $\varepsilon > \varepsilon''$, the mating is with a close partner and each child's health (and the average) is $h_i = \frac{\delta\varepsilon}{2}$. For $\varepsilon' < \varepsilon < \varepsilon''$, see the proof of Proposition 1. (c): It follows from the proof of Proposition 1 and from (a)+(b) that $\frac{\tilde{h}_2}{\tilde{h}_1} = 1$ for $\varepsilon < \varepsilon'$ and $\varepsilon > \varepsilon''$ and $\frac{\tilde{h}_2}{\tilde{h}_1} = \alpha < 1$ for $\varepsilon' < \varepsilon < \varepsilon''$. QED.

2.4 The role of the spatial distribution

An extension to the last point may consider the role of the spatial distribution of genome. This issue may be addressed from two perspectives, i.e., comparative statics with respect to population density and changes in the spatial correlation of genome over generations.

Spatial distribution of genome is related to population density through distance between settlements with genetically different inhabitants. Population density enters the analysis twice. First, health may be related to population density through the distance to health care providers and the overall level of development (Ashraf & Galor 2013). Correspondingly, Equation (4) may be rewritten as

$$h_i = k e_i \delta \tag{5}$$

where k is the population density. From the analysis in Section 2.2, it follows that if ε'' is the threshold level of wealth that distinguishes between genetically remote and close mating in the benchmark model, the threshold under Equation (5) is $\frac{1}{k}\varepsilon''$.

Second, the cost of mating a genetically remote partner is lower when genetically remote individuals live closer to each other. The two effects combined imply that both ε' and ε'' decrease in k. Therefore, the segment of the population that exercises a genetically remote partnership has a lower level of wealth when the population density is higher. It means that genetic diversity in the next generation increases in a poorer segment of the population as a function of population density.

Another issue is the dynamics of the spatial correlation of genome. Because marriage with genetically remote partners is the strategy of the segment of the population with an intermediate level of wealth, one should expect an asymmetric decrease in the spatial correlation of genome over generations. The poor and the rich preserve a high spatial correlation, while those with an intermediate level of wealth develop a low spatial correlation. This fragmentation of genome diversity and its development from generation to generation depend not only on the parameters of the model but also on the long-run effect of genome diversity on wealth on individual and macro levels.

3 Conclusions

Avoidance of inbreeding is an evolutionary strategy to provide healthy offspring. However, many individuals enjoy similarity with their children, even though the propensity of similarity decreases in the genetic distance between the parents. Historical examples of inbreeding practices among powerful dynasties suggest the possibility that the inbreeding-born children's health problems can be to some extent compensated using material resources. It leads to a non-trivial relationship between wealth and health. In particular, mating genetically remote partners and discrimination in favor of more similar children may be the strategy of individuals with an intermediate level of resources, while those with low and high levels of resources mate genetically close partners. The poor cannot mate geographically (and genetically) remote partners, while the rich may prefer to keep the blood "pure" but can afford better nutrition and expensive medical treatments for their children.

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