# For Whom the Bell Curve Tolls: A Lineage of 410,000 Individuals 1750-2020 shows Genetics Determines most Social Outcomes

Gregory Clark, UC Davis

Economics, Sociology, and Anthropology are all dominated by the belief that social outcomes are principally created by parental investment and community socialization. Employing a lineage of 410,000 English people 1750-2020 we test whether such mechanisms better predict outcomes than a simple additive genetics model. The genetics model predicts better in all cases except for the transmission of wealth. The high persistence of status over multiple generations, however, would require in a genetic mechanism strong genetic assortative in mating. This has been until recently believed impossible. There is however, also strong evidence consistent with just such sorting, all the way from 1837 to 2020.

## 1. Introduction

It is widely believed that while social status - measured as occupational status, income, health, or wealth – is correlated between parents and children, this correlation is driven by parental investments in children, or by cultural transmission.[1] This belief has profound influence on peoples' perception of the fairness of social rewards, of the need for government intervention in the lives of disadvantaged children, and of the social value of education.

In this paper I test whether culture/human capital or genetics offers a better explanation of the inheritance of social attributes, using a lineage of 410,000 English individuals 1750-2020. To do so we have to specify both a general model of cultural/human capital inheritance, and one of genetic inheritance. There is already a well established model of additive genetic inheritance, formulated by Fisher in 1918. This I test against the data below. Specifying a model of cultural/human capital transmission as an alternative is more difficult. The ways culture/human capital has been hypothesized to operate are many and varied.

[1] Studies of adoptions and of twins suggest that this belief is not well founded. Such studies suggest that genetic transmission explains the majority of social outcomes, but leave room for substantial social influences. See, for example, Sacerdote, 2007.

## A Socio-Genetic Model of Inheritance

Most complex human traits are influenced genetically not by single variants in the DNA sequence, but by the additive effect of many locations in the DNA where there are variants in the base pairs, where each location itself has a very small effect on the trait in question. Height, for example, is inherited in just this polygenic way. For each location on the genome, i, where variants have an influence on height we can assign a score of $d_i$ = 0, 1 or 2, depending on whether a person has 0, 1 or 2 copies of the tall variant across *n* locations. We can then assign a predicted height to the person

$$H = \sum_{i=1}^{n} a_i d_i \tag{1}$$

where $a_i$ reflects the effect of the polymorphism i on predicted height. For height there are believed to be at least 300 locations that matter in height determination. Table 1 illustrates the process:

**Table 1: Determination of Genotypic Value with Additive Inheritance**

| Locus | Allele Value | Weight | Effect |
|---|---|---|---|
| 1 | $v_1 = 0,1, or2$ | $w_1$ | $w_1 \times\ v_1$ |
| 2 | $v_2 = 0,1, or2$ | $w_2$ | $w_2 \times\ v_2$ |
| 3 | $v_3 = 0,1, or2$ | $w_3$ | $w_3 \times\ v_3$ |
| ….. | | | |
| n | $v_4 = 0,1, or2$ | $w_n$ | $w_n \times\ v_n$ |
| All | | | $\sum_{i=1}^{n} w_i v_i$ |

This type of genetic inheritance is called additive because the effect at each location is just the additive sum of how many height positive variants a person has at that location. Also the overall genetic effect is just the addition of the effects at each location. There are no important supplementary effects from dominant or recessive genes, and no interactive effects from combinations across the different loci on the genome. Thus this is a very simple and clear model of the intergenerational transmission of social status. In a famous paper in 1918 Ronald Aylmer Fisher showed what the implications of this type of transmission of status would be for the correlation between all members of a family tree under different types of assortment by parents (Fisher, 1918). The key assumption of this model is that the environment has little independent impact on outcomes.

When we come to social outcomes the idea here will be that people inherit a set of abilities that determine, whatever their parents' circumstances, their ultimate outcome in terms of occupational status, education, health or longevity. For wealth, where there is an actual transfer between generations, we would not expect the Fisher rules to hold.

To model this additive genetic transmission we denote the genotype value of a person on any trait as x, and the corresponding phenotype as y. For any individual the phenotype is generated from the genotype, with some random component. This random component can be very small, as with the 10 digit ridge count on your fingers. Or it can be very large, as with adult longevity.

$$y_t = x_t + u_t \qquad (2)$$

If we denote the genotypic value of the fathers as $x_f$ and of the mother as $x_m$, with then the genotype of a child will be[2]

$$x_c = \left(\frac{x_f}{2} + \frac{x_m}{2}\right) + e_t = \bar{x}_p + e_t \qquad (3)$$

In this case the hereditability of the trait, the proportion of phenotype variance explained by the genotype variance, will be the regression coefficient of the child phenotype on the average of the parent phenotype which is

$$h^2 = \frac{var(\bar{x}_p)}{var(\bar{x}_p)+var(\bar{u}_p)} = \frac{\sigma_x^2}{\sigma_x^2 + \sigma_u^2} = \frac{\sigma_x^2}{\sigma_y^2} \qquad (4)$$

Note that with respect to the average of the parents the genotype does not regress to the mean for children. But for individual parents there will be regression to the mean, however, which will depend on the degree of genetic assortment in mating.[3]

[2] The random error component e represents the randomness of which alles are inherited from each parent, and from the fact that there is not in fact a 50:50 split in allele inheritance by parent.
[3] A person of high or low genotypic value for a trait will usually match with someone of lower genotypic value.

Let the correlation between the genotypes of the parents on the relevant characteristics be *m*, and let the matching of parents be based solely on the genotype. Then the correlation in genotype between child and a single parent will be

$$\left(\frac{1+m}{2}\right)$$

Consequently the intergenerational correlation between a single parent and a child will be

$$h^2\left(\frac{1+m}{2}\right)$$

Note that this will also be the correlation between siblings.

If, however, parents are matching on the phenotype for this trait, and that phenotype correlation is r, the single parent-child correlation is now

$$h^2\left(\frac{1+r}{2}\right)$$

Note also that the genotype correlation between the parents will now be $m = h^2 r$, and so is less than the phenotype correlation. Now the correlation between siblings is

$$h^2\left(\frac{1+rh^2}{2}\right) = h^2\left(\frac{1+m}{2}\right) \qquad (5)$$

Table 2 shows the expected correlation between various relatives on either of these two types of assortment by parents. These correlations can be extended all the way down the family tree. It is notable that these correlations depend only on $h^2$, and m or r, as well as the degree of genetic distance between members of the tree.

Figure 1 shows the pattern of correlations as a function of genetic distance in the family tree, for the case where the parents match on the genotype. The vertical axis shows the correlation between family members, on a logarithm scale. The horizontal axis shows how many steps apart the parties are on the family tree. In practice this is the only type of matching in marriage that is consistent with the data given below, so we concentrate on this case. Figure 2 shows equivalently the correlation in phenotype as a function of fraction of genes shared, drawn for the case where *m = 0.6*. the decline of correlation across generations is by a factor of $\left(\frac{1+m}{2}\right)$. In the equivalent figure where *m = 0*, the implied phenotype correlation would drop by a half for each step in the family tree.

**Table 2: Correlations between relatives with assortative mating**

| Relative to Child | Parents Match on Genotype | Parents Match on Phenotype |
|---|---|---|
| Single parent | $h^2\left(\frac{1+m}{2}\right)$ | $h^2\left(\frac{1+r}{2}\right)$ |
| Sibling | $h^2\left(\frac{1+m}{2}\right)$ | $h^2\left(\frac{1+m}{2}\right)$ |
| Grandparent | $h^2\left(\frac{1+m}{2}\right)^2$ | $h^2\left(\frac{1+m}{2}\right)\left(\frac{1+r}{2}\right)$ |
| Uncle | $h^2\left(\frac{1+m}{2}\right)^2$ | $h^2\left(\frac{1+m}{2}\right)^2$ |
| Cousin | $h^2\left(\frac{1+m}{2}\right)^3$ | $h^2\left(\frac{1+m}{2}\right)^3$ |
| 2nd Cousin | $h^2\left(\frac{1+m}{2}\right)^5$ | $h^2\left(\frac{1+m}{2}\right)^5$ |

Note: *m* is the correlation of parents on the relevant genotype, *r* the correlation on the relevant phenotype. Source: Fisher, 1918, Crow and Felsenstein, 1968, Nagylaki, 1978.
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**Figure 1: Outcome Correlations as a Function of Genetic Distance, Matching on Genotype**

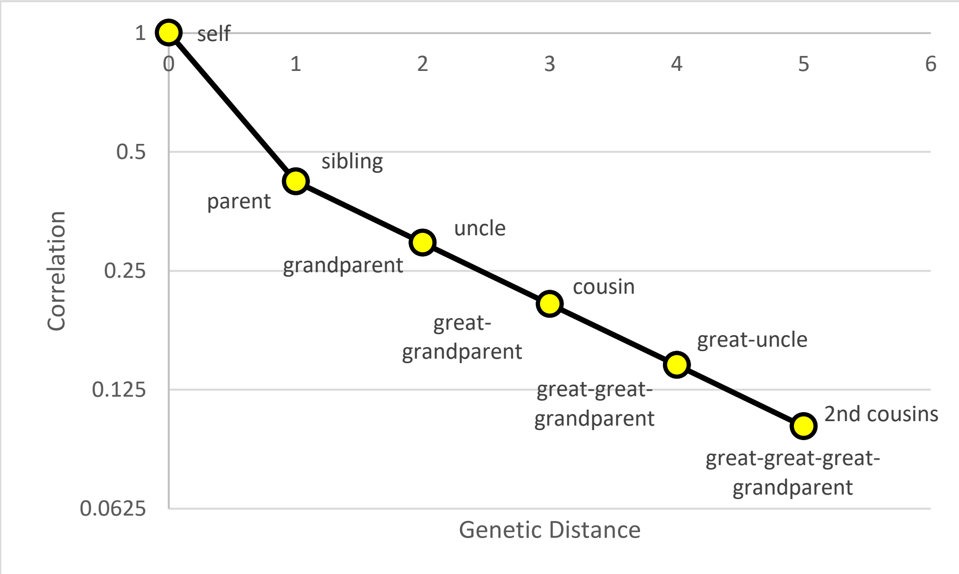
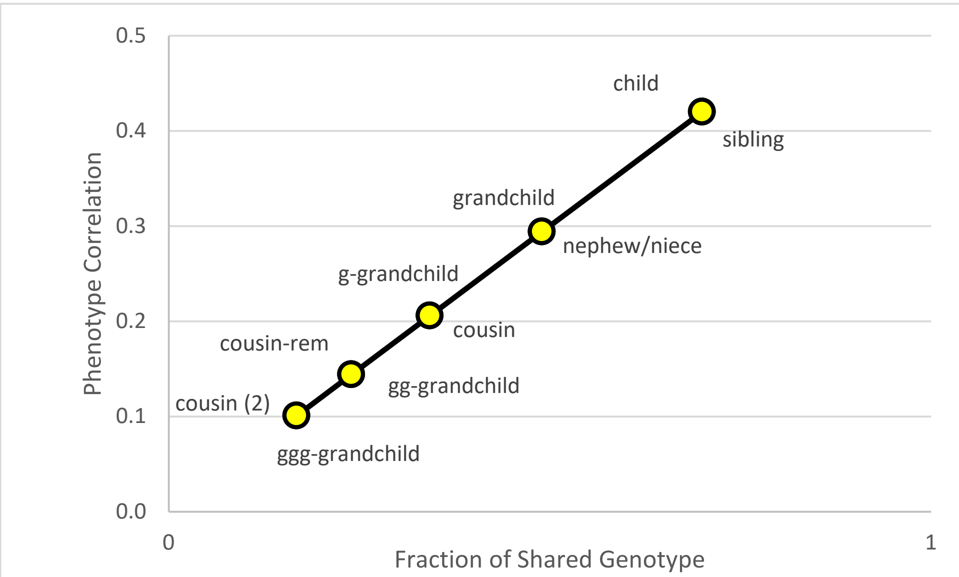



**Figure 2: Implied Correlation Pattern with Additive Genetic Determination of Outcomes: Assortment on the Genotype**



There is a linear connection between the outcome correlations and the fraction of shared genotype. Thus empirically we can estimate $h^2$ and m by estimating the parameters of the expression

$$\ln(\sigma_n) = \ln(h^2) + nln\left(\frac{1+m}{2}\right) \qquad (1)$$

where *n* is the relative genetic distance between two relatives in the genealogy.

The reason I have labelled this a **socio-genetic** model of social status is that the crucial parameter m, marital assortment, is completely socially determined. There is no intrinsic reason that people should match in marriage based on their social abilities. They could match purely on physical characteristics, or on personality traits unrelated to social and economic outcomes. They do match, in some societies, on whatever cousins are available of the appropriate age and gender. Interestingly, though, if matching is just to a random cousin then in equilibrium in such a society m will be quite low at around 0.23, whereas in England the evidence for m, as mentioned, in in the order of 0.6-0.8.

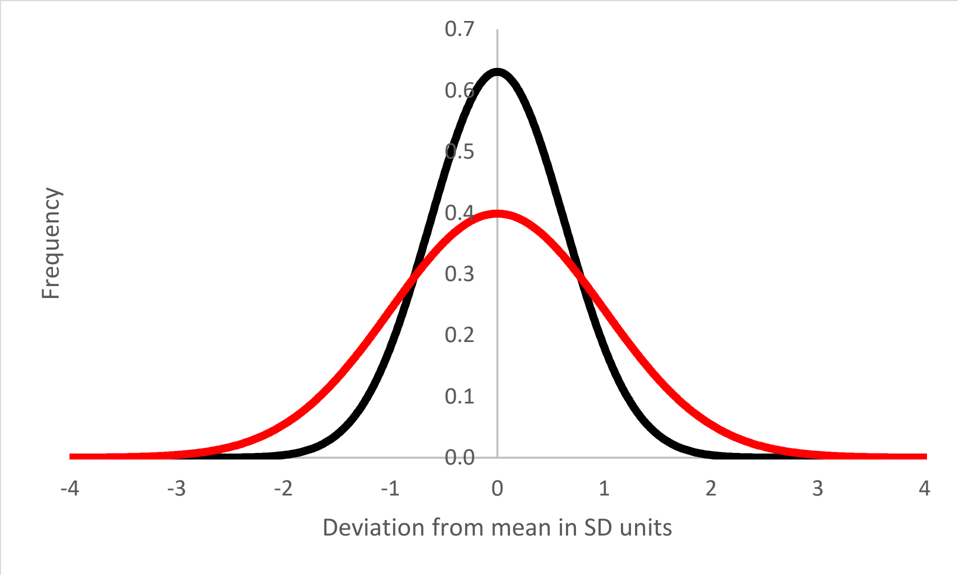
This social choice around marriage has profound implication in a world of genetic transmission for the overall individual distribution of social abilities in society, and for the rate of social mobility. In equilibrium the distribution of the genes for overall social abilities will be

$$\sigma_x^2 = \frac{\sigma_e^2}{1-\left(\frac{1+m}{2}\right)} \qquad (6)$$

where $\sigma_e^2$ is from equation (3) the randomness in the shuffling of genes between generations. Figure 3 shows what will happen to the distribution as m increases. These effects are initially modest, but get very substantial as m rises. This for m = 0.6 compared to m = 0, the standard deviation of social abilities will be in equilibrium 1.58 times the no assortment value. If m got as high as 0.8 the standard deviation would be 2.24 times the value in absence of assortment.

Again as we increase m from 0 to 0.8 it would make the long run correlation in underlying status rise from 0.5 to 0.9.

**Figure 3: Marital Assortment and the Social Distribution of Abilities**




## Testing the Socio-Genetic Model

Additive genetic transmission of status generates a number of interesting and testable implications, that will be examined below using the Families of England database.

### 1. Pattern of Correlations in a Family Tree

The first implication is that the correlation between relatives in a family tree declines at a constant rate $\frac{(1+m)}{2}$ where m is the genotype correlation of the parents. So long run social mobility rates depend purely on the degree of genetic assortment in marriage. Also the decline in correlations should follow a very regular pattern.

For example, if we take people in a family tree who are roughly contemporaneous, siblings, cousins, 2nd cousins, 3rd cousins and so on, then the predicted correlations between them under either type of marital assortment would be

| | | | |
|---|---|---|---|
| Siblings | $h^2\left(\frac{1+m}{2}\right)^1$ | Cousins | $h^2\left(\frac{1+m}{2}\right)^3$ |
| 2nd Cousins | $h^2\left(\frac{1+m}{2}\right)^5$ | 3rd Cousins | $h^2\left(\frac{1+m}{2}\right)^7$ |

We can test whether we observe such a pattern of correlations for a variety of outcomes.

## 2. Siblings

The second interesting implication is that whatever the mechanism of marital assortment, the parent child correlation in status will equal or exceed that of siblings. This is a surprising and unexpected conclusion from the perspective of those who would give a large role to family environments in social outcomes. Children share the same parents, life in the same house, are located in the same community. They do not share parents with their parents, or the same house, or the same community. Further we observe regression to the mean between individual parents and their offspring in terms of social outcomes. If this is to be driven by family environments then there have to be systematic differences in family environment between parents and children. So on any environmental account of social accounts the correlation between children should be greater than that between parent and child. So this constitutes an interesting test of these competing accounts of social outcomes.

## 3. Type of Parental Assortment

The pattern of correlations among relatives will also reveal whether parental assortment is through the phenotype or the genotype. With assortment on the phenotype the parent child correlation will exceed that of siblings. If assortment is on the genotype then these correlations will be equal. Also with assortment on the phenotype the grandparent-child correlation will exceed the uncle/aunt-child correlation. With assortment on the genotype these correlations will again be equal.

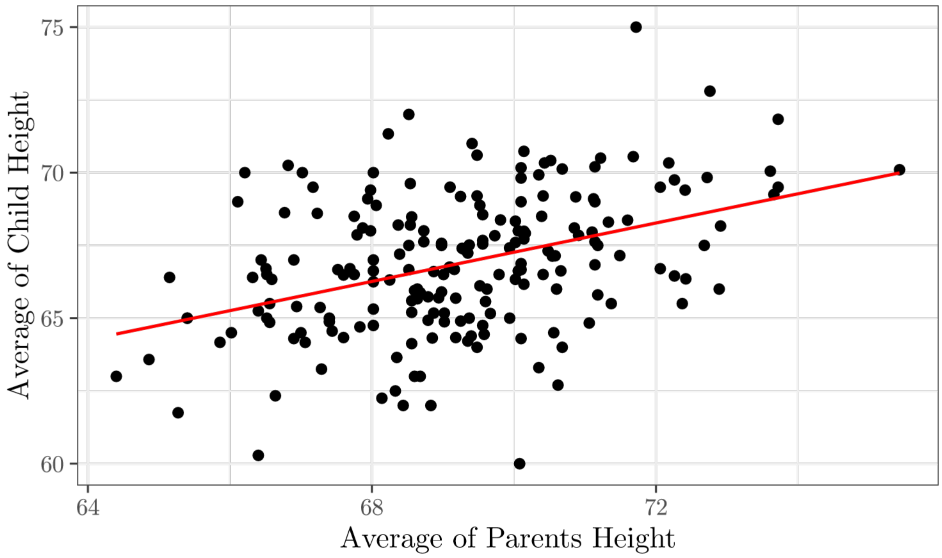
## 4. Gender Symmetry

With genetic transmission of social outcomes there should be a strict symmetry of correlations between the paternal and maternal side of the family. The correlation, for example, in any outcome between the paternal grandfather and child should equal that between the maternal grandfather and child. In contrast with social transmission of social outcomes we can imagine significant asymmetry. Property may descend more through the male than the female line. Occupational opportunities can be linked more closely to the maternal line than the maternal, where there are family businesses.

## 5. Linearity of Regression to the Mean

Another implication of the additive genetic model is that there will be linearity in the regression to the mean observed between generations. The rate of movement to the mean will be the same all across the distribution of parental characteristics. It will be the same

**Figure 4: Linearity of Regression to the Mean with Height**




Source: Galton (1886)

for the bottom 1% as for the top 1%. There will thus be no "wealth traps" or "poverty traps" where children of parents at the extremes of the social distribution show unusual persistence in their characteristics, as would potentially appear in social mechanisms of inheritance.

A good model for additive genetic inheritance in modern high-income societies is height, which is largely genetically inherited, and is the outcome of at least 300 genes each of which exerts very modest influence. Height inheritance certainly meets the second stipulation for the correlation pattern set out in table 1. Regression to the mean is indeed, at least to a first approximation, linear across the whole range of parent heights as figure 1 shows. The figure shows the heights of parents and children in Galton's pioneering study of the inheritance of heights. Height inheritance thus fits well this additive genetic model. Also, plausibly, mating actually sorts on the height phenotype rather than the underlying height genotype. So for height the long run intergenerational correlation should be close to 0.5.

## 6. Family Size

Exogenous shocks to family size should produce no effects on child outcomes. In England the evidence is that for marriages earlier than 1880 there was no attempt to control fertility. From the perspective of the parents family size was random.

## 7. Birth Order

Outcomes should be independent of birth order, except potentially for wealth where there are social rules of inheritance that can favor the first born, or all males.

## 8. Living Versus Dead Relatives

The correlations between individuals in a lineage should be unaffected by whether they ever interact. The status of living grandparents should predict child outcomes no better than dead relatives. In this model status is inherited as a first order Markov process, with only the parents genetics mattering. The relatives merely provide information on the underlying genotype of the parents. The amount of information they provide will be a function of their genetic distance from the parents.

## 9. Detecting the Underlying Genetic Correlations

A further implication of the pattern of correlations found in table 1 is that if we estimate the correlations between relatives in table 1 for one measure of social status, but instrument with instead the status of a relative, then when the OLS correlation is

$$h^2(\frac{1+m}{2})^n$$

the instrumented correlation will be

$$(\frac{1+m}{2})^n$$

**An Economic Model of Social Status?**

It would be great if there was a well accepted economic model of social status determination whose predictions we could contrast with the predictions of the socio-genetic model above. But economics has made little progress in developing a testable model of social status. The workhorse model of intergenerational social mobility in economics is that of Becker and Tomes (1979), now more than 40 years old. That model, as explicated by Solon (1999), assumes a parent (generation $t - 1$) and one child (generation t), where the parent allocates their lifetime earnings $y_{t-1}$ between their own consumption $C_{t-1}$ and investment $H_{t-1}$ in the child's earnings capacity. Parents cannot borrow on behalf of their children to invest in their human capital because of imperfect capital markets. Children also inherit abilities E from the parent. With this specification

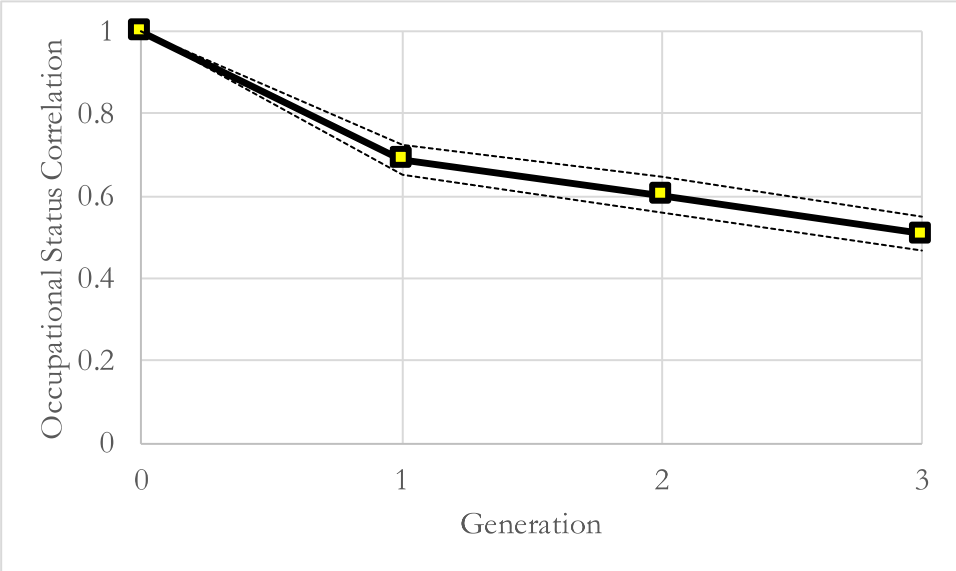
$$y_t = (1 + r)H_{t-1} + E_t \quad (7)$$

where r is the return to human capital investment, and $E_t$ is child ability. As Goldberger (1989) points out the predictions of this model are not distinguishable across from a model of simple regression to the mean. Since the model assumes one child it can say nothing about what to expect is the correlation in outcomes of siblings. With multiple children it could be that parents invest more human capital in the one with less talent to compensate, or it could be that they invest more in the talented offspring because the returns are greater. The only essential takeaway is that investment in human capital matters, and that social institutions which provide that investment socially should reduce the parent-child correlation of outcomes.

This means there are some predictions that we can test with the lineage data. The first is that positive shocks to wealth in the parent generation should transmit to greater human capital in the child generation (and thus higher occupational status). The second is that, though this steps outside the model which assumes one child per family, shocks that increase family sizes should under most assumptions, reduce child outcomes since there will be fewer resources per child. Another prediction would be that early deaths of either parent will reduce the resource flow to children and hence reduce their educational and occupational outcomes.

But as we shall see there is nothing in the Becker/Tomes framework that predicts or captures some unexpected patterns that appear clearly in the lineage data, such as that of figure 5. This figure shows exactly the pattern predicted in the socio-genetic model (figures 1 and 2) of correlations across multiple generations. To have an alternative to the socio-genetic model we need to have at least a model that would produce figure 5.

**Figure 5: Occupational Status Correlations across Multiple Generations, England, births 1780-1930**




Note: The dotted lines show the 1% confidence intervals around each estimated correlation.

## A Cultural Model of Inheritance

One model that would capture the intergenerational pattern of figure 5 is as below. Suppose that social outcomes, $y$, are the product of the family culture/environment, $z$, and some random component, $u$, so that

$$y_{it} = z_{it} + u_{it} \ .^{4} \qquad (8)$$

Suppose also that the family culture/environment is regressing to the mean at rate (1-b). Then

$$z_{it} = bz_{it-1} + e_{it} \ . \qquad (9)$$

$e_t$ is a random component that must exist to keep the dispersion of family culture $z$ constant across families across generations.

With this structure the average correlation of social outcomes between parent and child will be

[4] In all cases in this paper variables are measured with mean 0, so that we can dispense with intercept terms in the equations.

$$\hat{\beta} = b\frac{\sigma_z^2}{\sigma_z^2+\sigma_u^2} = \theta b \qquad (10)$$

The correlation between siblings, sharing a common environment, $z_t$ , will on average be

$$\hat{\rho} = \frac{\sigma_z^2}{\sigma_z^2+\sigma_u^2} = \theta \qquad (11)$$

Thus the sibling correlation will exceed the parent-child correlation on this cultural inheritance model. Note that this occurs even though we have left plenty of room for random influences on the outcomes among siblings exposed to common family culture. Between parent and child there is always the extra element of difference in that culture that does not exist for children. With b = .8, the sibling correlations will exceed the parent-child by 25%.

With the structure of inheritance embodies in equations (8) and (9) we can predict the correlations of any two relatives in a lineage. Thus

| | |
|---|---|
| Parent | $\theta b$ |
| Sibling | $\theta$ |
| Uncle/Aunt | $\theta b$ |
| Grandparent | $\theta b^2$ |
| Cousins | $\theta b^2$ |
| Great Grandparent | $\theta b^3$ |

In particular the correlation between children and their parents should be less than that between children. The correlation of children and their parents should be the same as between children and their aunts and uncles. Also the correlation between children and their grandparents should equal that of children and their cousins. This is a different pattern of correlations than predicted in the socio-genetic model.

## Status Determination in an English Lineage

We can test whether the cultural or additive genetic model of inheritance works predicts better using a lineage under construction for English families 1670-2020, that shows all familial links, plus a variety of social outcomes. So far we have the familial connections of all the people in the lineage (410,395), but only social outcomes for a subgroup of people. Figure 6 shows a sample lineage for one couple and some of their descendants from the database. The figure illustrates the richness of the set of family links that the database contains. In this case the lineage covers 7 generations. Table 3 shows thre numbers of unique pairs of relatives in the database as a whole, and in two subgroups: general status family lineages, and lineages which were deliberately selected to have elite status in the early nineteenth century. There is potentially an enormous amount of data on the social status of relatives of all types of degree of connection. However, we are still accumulating status markers for people, so that we shall see the numbers of pairs with different types of status indicators is much smaller.

Here we can employ 6 distinct measures of status.

## Social Outcomes 1999-2021

We have three raw measures of social status for members of the genealogy alive 1999-2021, constructed for persons aged 25 and above at the time of observation. From these we also construct a fourth aggregate social status measure.

(1) Average dwelling value for the street in which the person was recorded living on an electoral roll 1999-2021. These house values correlate well with occupational status, where we know the occupation of people in the FOE database, with a correlation of 0.43. Since average dwelling values vary substantially across the regions of the UK, and people show strong locational persistence across generations, these values were adjusted as described in the appendix to remove most of the regional differences. Since house values have a highly asymmetric distribution, the natural logarithm of these values was used to have an outcome with a closer to normal distribution.

(2) The index of multiple deprivation for the census tract the person was living in when recorded on the electoral roll. The index used is the one from 2001. The score used is the percentile rank of a tract with 100 being the area of lowest social deprivation. The area covered by each census tract is around 1,600 people. This measure again correlates with occupational rank (0.22).

**Figure 6: An Illustrative Portion of a Family Lineage, Lineage Database**

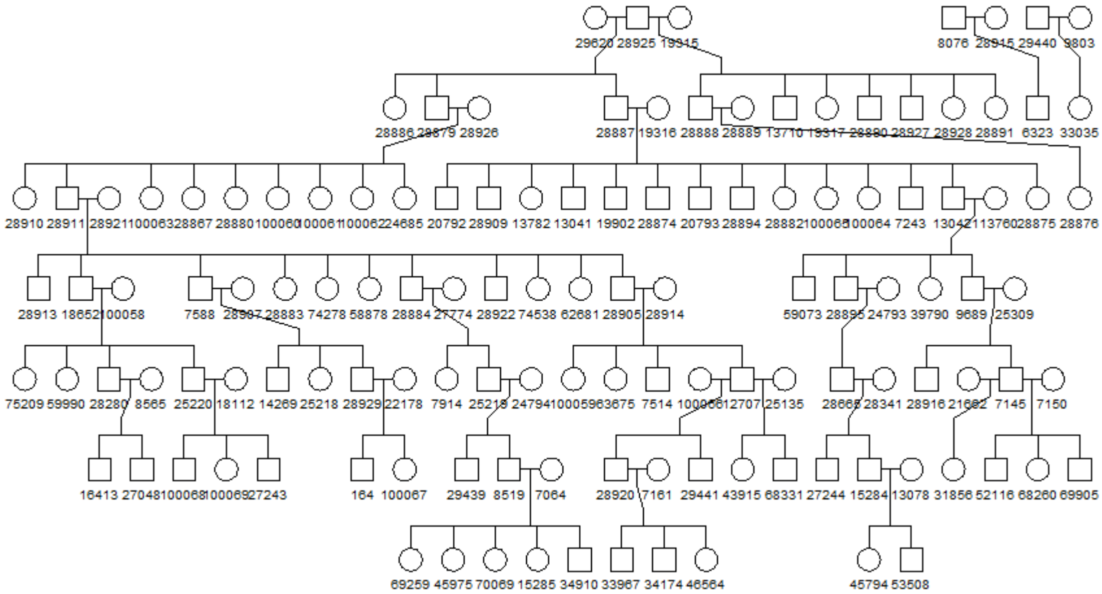


**Table 3: Relatives in the FOE genealogy**

| Relationship | Genetic Distance | all | General Lineages | Elite Lineages |
|---|---|---|---|---|
| Child | 1 | 467,382 | 407,366 | 60,016 |
| Sibling (full) | 1 | 535,445 | 490,314 | 45,131 |
| Nephew/Niece | 2 | 1,032,431 | 931,443 | 100,988 |
| Grandchild | 2 | 444,140 | 387,098 | 57,042 |
| Cousin | 3 | 813,976 | 758,480 | 55,496 |
| Cousin once Removed | 4 | 1,739,709 | 1,591,810 | 147,899 |
| 2nd cousins | 5 | 1,174,491 | 1,114,120 | 60,371 |
| 3rd cousins | 7 | 1,466,883 | 1,420,013 | 46,870 |
| 4th cousins | 9 | 1,528,906 | 1,486,340 | 42,566 |

**(3)** An indicator for whether the person was a director of a public company in 2021. This was more likely to be the case for men, so gender norms were used. This measure again correlated with occupational status, with a correlation of 0.3.

(4) We combine these measures into an overall index of social status using Principal Component Analysis. This combined status index is labelled *statmod*.

These measures are described further in the appendix. We measure house values and the index of multiple deprivation just for individuals aged 25 and above at the date of the observation since younger individuals are likely to be still living with their parents.[5] To further exclude such observations we exclude parent-child and sibling pairs where the partners share a postcode.

These social status measures are all correlated for the individuals in the genealogy. The correlation of the ln house value and the index of multiple deprivation is 0.53, and for the average house value and being a company director 0.24. The normed house values also correlate with occupational rank

**Fit of the Socio-Genetic Model**

Table 4 shows for normed ln house value the pattern of correlation between all relatives in the genealogy up to 3rd cousins. Also shown is the average date of birth of their nearest common ancestor. For 3rd cousins this is 1829. For people who are second cousins and beyond we would expect no social contact. One thing that appears very clearly is that even 3rd cousins have significantly correlated house values, even though the raw values have been normed to exclude regional effects.[6] We checked these effects were not spurious by forming random matches in the genealogy database between people with house value information. That produced a precisely estimated correlation of 0.

When we estimate the parameters of equation (1) using this data the implied value of b is .81 with a standard error of 0.02. The persistence of status is very strong across the lineage. The implied value of m is 0.62 but with a larger standard error of 0.04. In figure 7 the $R^2$ of the linear fit is 0.95. Figure 8 shows the pattern of correlations against the implied shared genetic material, using the estimated value of m from fitting equation (1). Also shown is the estimated linear fit. The intercept of that fit is not significantly different from 0. The implied genetic correlation of parent to child, and of siblings is 0.8.

[5] Where a person has different addresses for different years in the electoral roll, we take the address they were at closest to age 40.

[6] The regions were London, South East, South West, Midlands, North, Wales, Scotland.

**Table 4: Correlation of Normed ln House Value, 1999-2021, by relationship**

| Relatives | Number | Ave Birth Year | Birth Year Common Ancestor | Correlation | Standard Error |
|---|---|---|---|---|---|
| Sibling | 5,290 | 1956 | 1924 | 0.303 | 0.017 |
| Child | 6,343 | 1967 | 1938 | 0.332 | 0.015 |
| Nephew/Niece | 6,222 | 1968 | 1906 | 0.260 | 0.024 |
| Cousin | 5,636 | 1955 | 1890 | 0.202 | 0.029 |
| Cousin-removed | 7,551 | 1966 | 1873 | 0.186 | 0.025 |
| Cousin2 | 6,250 | 1953 | 1856 | 0.170 | 0.024 |
| Cousin2-removed | 9,497 | 1964 | 1840 | 0.119 | 0.014 |
| Cousin3 | 6,565 | 1957 | 1829 | 0.075 | 0.025 |

Notes: Standard errors clustered by most recent common ancestor.

**Figure 7: Ln House value correlations and genetic distance**

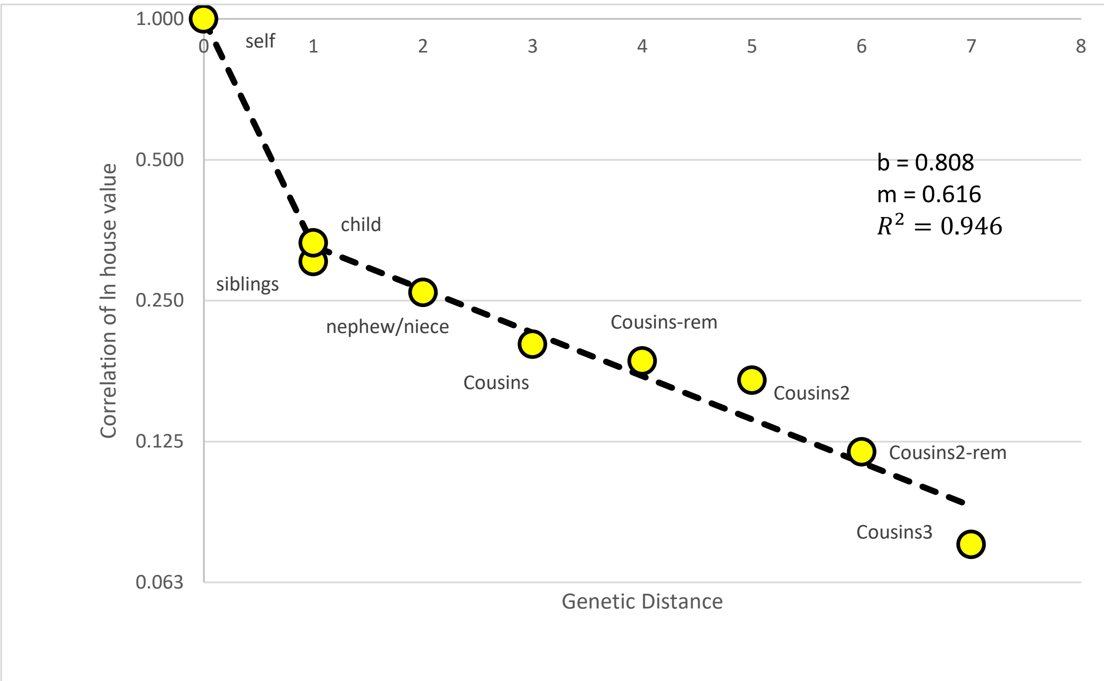
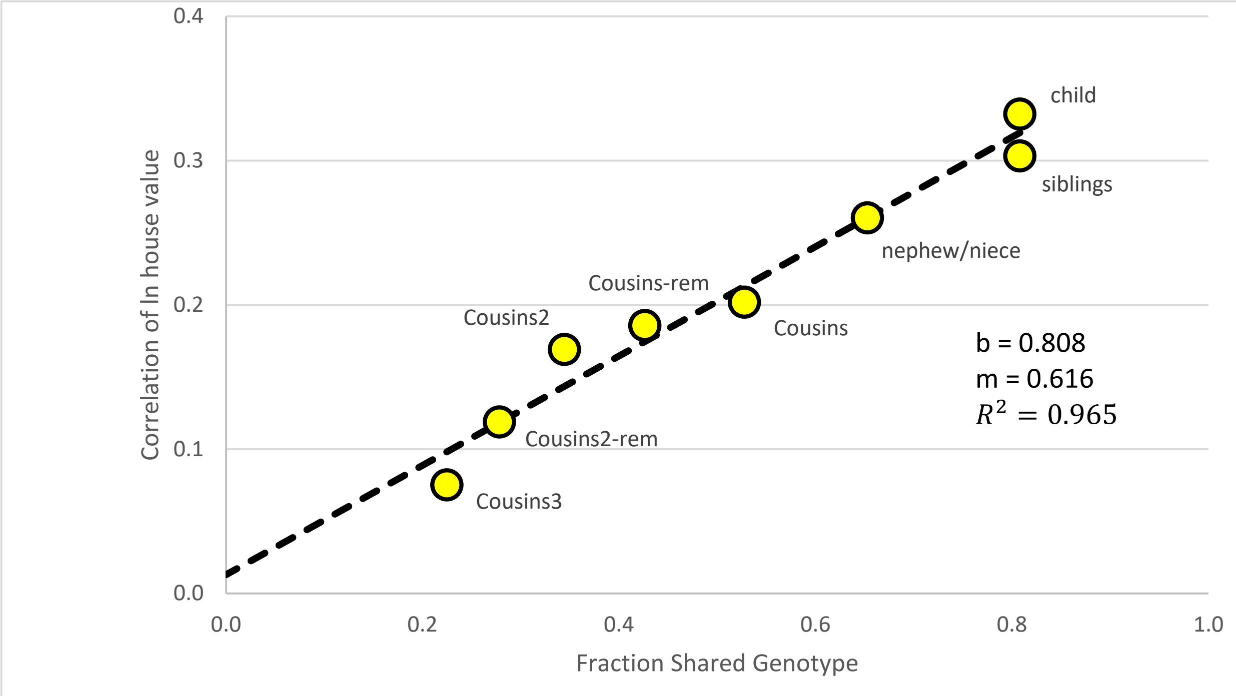


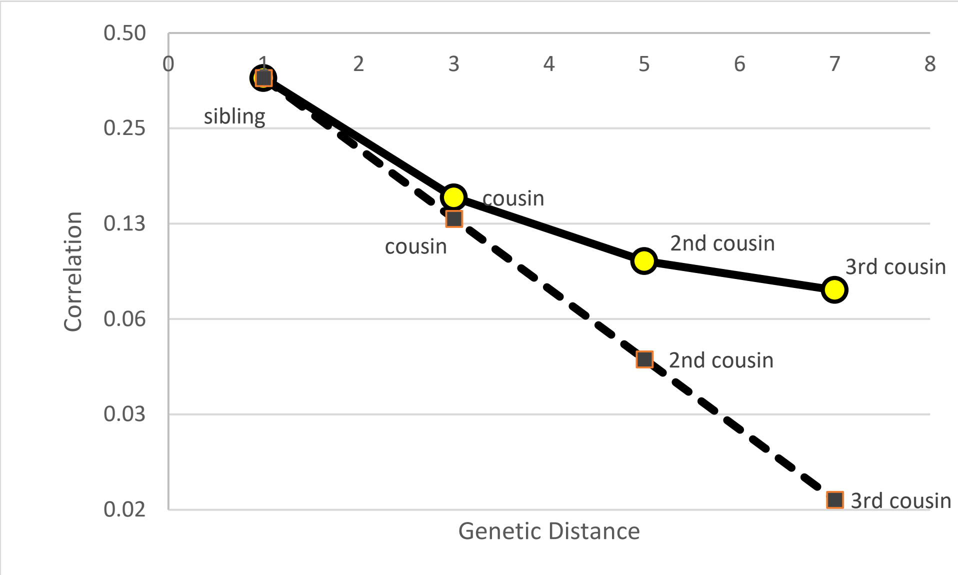
**Figure 8: House value correlations and genetic distance**




It is widely expected that between 1800 and 2021 the intergenerational correlation in social outcomes between parents and children will have declined significantly. For generations before 1873 there was no legal requirement to educate children, and little public provision of even elementary education. Increasingly after 1873 the state has provided more years of education, and taken out of parental control much of the decision about how much education to supply. There has also been state provision of housing and nutrition for poorer families. We would thus expect a decline in heritability of social traits over these years.

If that decline in heritability led to a decline in genetic marital assortment (because of the looser association between genotype and phenotype), then there will not be a linear relationship between the genetic distance of relatives in a genealogy and the logarithm of their social outcomes correlations as is predicted by equation (1). Third cousins, for example, born in 1980 will typically have a common ancestor born in 1830. If genetic marital assortment was higher in the pre-mass education era, then the contemporaneous correlation between 3rd cousins in social outcomes will be higher than predicted from the relative correlation of siblings versus first cousins. Figure 9 shows the expected correlation pattern with genetic distance with an increasing social mobility rate over time.

**Figure 9: Correlations with Genetic Distance with Less Genetic Marital Assortment in Recent Generations**




What we see, however, in figures 7 and 8 is a strict linearity in the relationship between the ln house value correlation and the genetic distance. This implies that the genetic marital assortment rates have been unchanged from 1860 to 1990, despite significant changes in social structure.

If we conduct the same exercise as above for the other three indictors of social status in recent times – the index of multiple deprivation, being a company director, or the combined index of social status – then we get very similar results. Table 5 summarizes these estimates. The underlying persistence of genetic status is around 0.8 in all three cases, and the implied marital assortment 0.6.

**Social Outcomes, births 1800-1919**

For people born in this date range we have three measures of social outcomes.

(1) Occupational Status at age 40 for men. We derived descriptions of occupations mainly from the censuses of 1841-1911, from the population register of 1939, from marriage registers 1837-1960. We convert these into an index of occupational status (0-100) using an equally weighted average of the ln wealth at death associated

with each occupation, with the average higher education attainment of men holding each occupation, and with the average fraction of men holding each occupation observed in school aged 11-19.

(2) Indicator for attainment of higher educational status for men. This indicator was scored as 1 if a man attended university or a military academy, or qualified as an attorney, chartered accountant, doctor, or architect, or was a member of an engineering society.

(3) Ln wealth at death relative to average wealth at death in the decade of death. This outcome is available for both men and women.

Table 6 shows the correlation in occupational status for men born 1800-1859 in the general lineage. Also shown is the year of their earliest common ancestor, which in the case of 4th cousins averages 1668. Even 4th cousins still have a significant correlation in occupational status, despite being the equivalent of 9 generations down within the lineage. We checked again that this was not just an artifact of the data by assigning men born 1800-69 in the average lineage a random relative within the lineage. In this case the correlation again drops to 0. As table 3 shows if we fit the parameters of equation (1) to this correlation pattern then the implied persistence rate across generations is 0.813 with a standard error of 0.022. The implied genetic correlation in marriage is 0.625 (with a standard error of 0.044). This persistence rate is remarkably similar to those of modern England shown again in table 3.

Figure 10 shows the implied shared genotype by relative as well as the observed correlation in occupational status. If we fit a line to the data in the figure the line intercepts the vertical axis at 0, and the $R^2$ of the fit is 0.94. The linearity of the fit implies that genetic marital assortment in England was the same from 1700 to 1859, and indeed the same as for 1860-1995. Again despite enormous social changes 1700-2000 we see a constant implied rate of assortment in marriage.

As noted table 5 summarizes all the estimates of the parameters of the additive genetic model for those born 1800-1995, and for 7 different social outcomes. The average value of the underlying persistence variable for the genotype is 0.8, and the implied degree of marital assortment 0.6. Interestingly though the estimated heritability of these different traits varies widely across trait and across time period, as figure 11 shows the implied underlying genetic persistence is close to 0.8 in almost all cases.

To summarize, from the extensive genealogy we have for families 1670-2021, the pattern of correlation in social outcomes is throughout consistent with additive genetic transmission with an intergenerational correlation in genotype value of 0.8, and a marital

**Table 5: Summary of Estimated Parameters 1800-2021**

| Outcome | Birth Period | Gender | b | m | $h^2$ | $R^2$ |
|---|---|---|---|---|---|---|
| Ln House Value | 1920-1995 | both | 0.808<br>(0.021) | 0.616<br>(0.042) | 0.404<br>(0.044) | 0.95 |
| Multiple Deprivation | 1920-1995 | both | 0.769<br>(0.025) | 0.538<br>(0.050) | 0.314<br>(0.043) | 0.94 |
| Company Director | 1920-1995 | both | 0.822<br>(0.080) | 0.644<br>(0.160) | 0.161<br>(0.072) | 0.52 |
| Social Status | 1920-1995 | both | 0.780<br>(0.020) | 0.559<br>(0.040) | 0.457<br>(0.050) | 0.96 |
| Occupational Status | 1800-1859 | male | 0.813<br>(0.022) | 0.625<br>(0.044) | 0.724<br>(0.105) | 0.91 |
| Occupational Status | 1860-1919 | male | 0.794<br>(0.029) | 0.625<br>(0.058) | 0.582<br>(0.120) | 0.88 |
| Higher Education | 1800-1859 | male | 0.800<br>(0.040) | 0.610<br>(0.080) | 0.593<br>(0.162) | 0.77 |
| Higher Education | 1860-1919 | male | 0.666<br>(0.067) | 0.332<br>(0.134) | 0.636<br>(0.405) | 0.74 |
| Wealth at Death | 1800-1859 | both | 0.841<br>(0.018) | 0.682<br>(0.036) | 0.505<br>(0.056) | 0.92 |
| Wealth at Death | 1860-1919 | both | 0.860<br>(0.017) | 0.720<br>(0.034) | 0.361<br>(0.038) | 0.91 |

**Table 6: Correlation of Occupational Rank, births 1800-1859, by relationship**

| Relatives | Genetic Distance | Count | Ave Birth Year | Birth Year Common Ancestor | Correlation |
|---|---|---|---|---|---|
| Son | 1 | 7,727 | 1838 | 1804 | 0.588 |
| brother | 1 | 7,765 | 1835 | 1801 | 0.547 |
| Nephew | 2 | 11,722 | 1840 | 1773 | 0.492 |
| Cousin | 3 | 9,585 | 1835 | 1767 | 0.494 |
| Cousin-removed | 4 | 10,106 | 1846 | 1752 | 0.353 |
| Cousin2 | 5 | 9,067 | 1835 | 1736 | 0.239 |
| Cousin2-removed | 6 | 13,690 | 1841 | 1712 | 0.148 |
| Cousin3 | 7 | 8,435 | 1836 | 1700 | 0.153 |
| Cousin3-removed | 8 | 14,198 | 1840 | 1676 | 0.126 |
| Cousin4 | 9 | 9,085 | 1837 | 1668 | 0.151 |

**Figure 10: Occupational Status and Shared Genotype, births 1800-59**

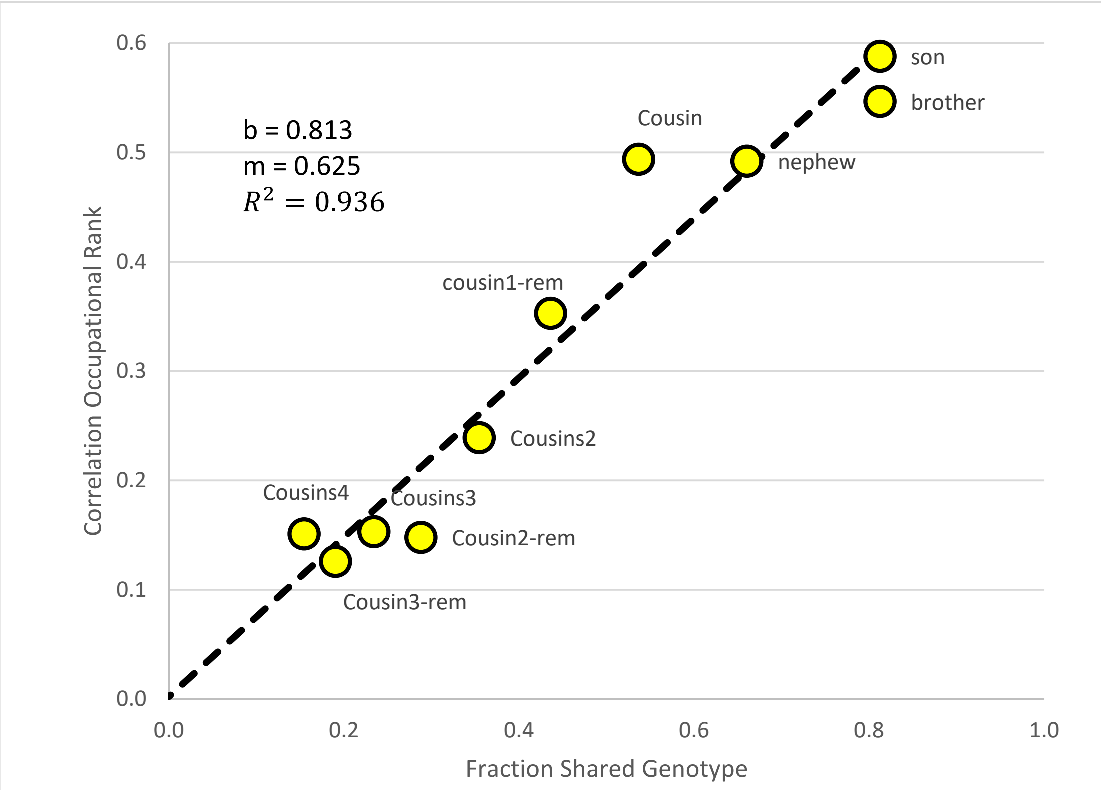
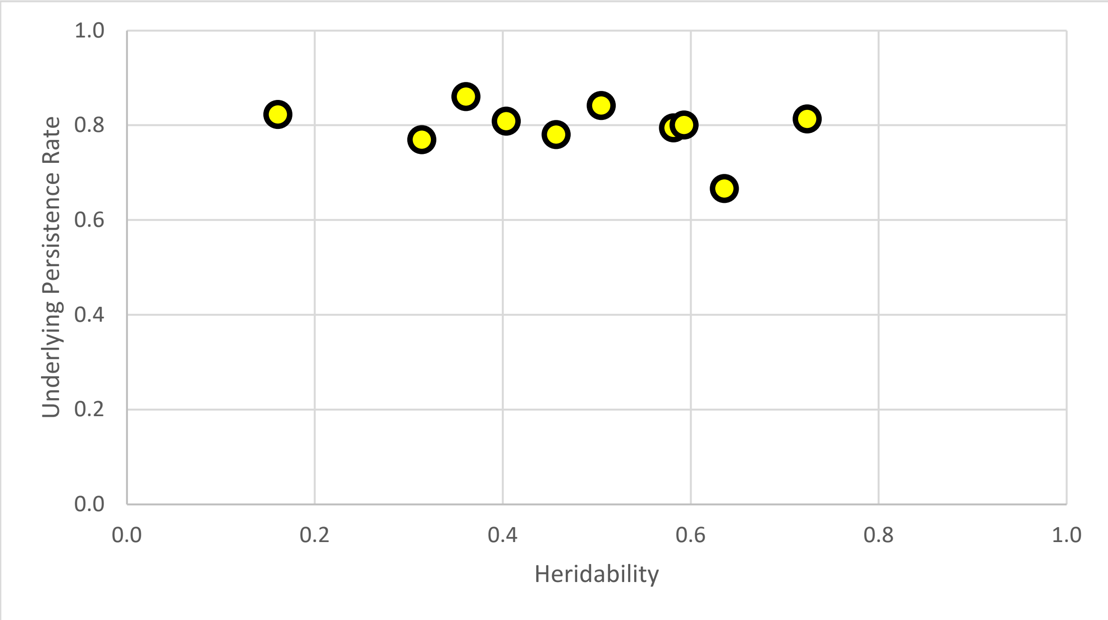


**Figure 11: Underlying Persistence Versus Hereditability of Social Traits**




correlation in genotype value of 0.6.

## Children Versus Siblings

Another prediction of the additive genetic model with assortment on the genotype that is hard to generate with cultural transmission is that the parent-child correlation on any trait should equal the sibling correlation. Figure 12 shows for average lineages in the whole FOE database the sibling correlation versus the parent child correlation for a set of traits with very different hereditabilities. Also shown is the 45 degree line of equal correlation. Again there is strong consistency with the predictions of the additive genetic model. The OLS fitted relationship between the correlation rates does not statistically differ from the 45 degree line. Parent child correlations predict sibling correlations with an $R^2$ of 0.97.

What can be decisively rejected is the cultural transmission model which posits significantly higher sibling correlations than those of parent and child. Another implication of the cultural model outlined above is that the correlation of children in status with their fathers should equal that with their uncles. With genetic transmission the uncle correlation is lower by a factor of $\left(\frac{1+m}{2}\right)$. Figure 13 shows these comparative correlations compared

**Figure 12: Comparative Father-Son and Sibling Correlations**

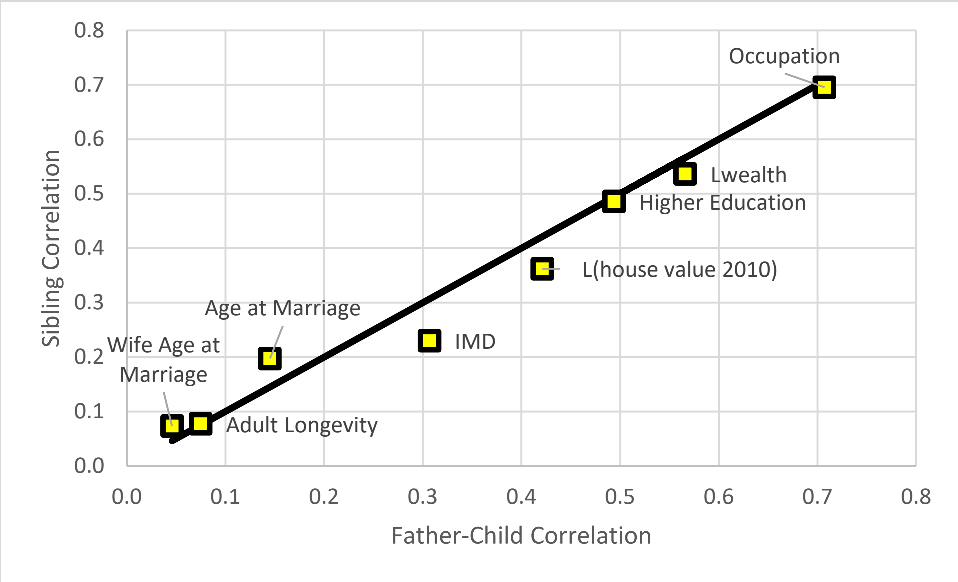
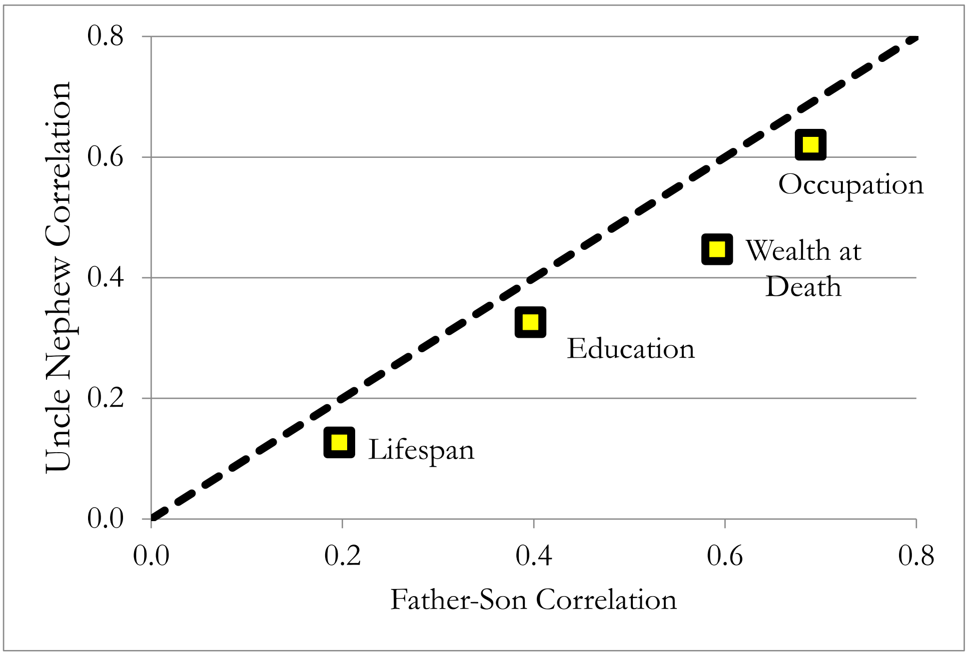



**Figure 13: Father versus Uncle Correlations**



with the prediction of the cultural model, which is that the correlations will fall along the 45° line. The pattern of correlations is again systematically at variance with the simple cultural model, and in line with the genetic model. The uncle-nephew correlations are all smaller than those of father-son. This suggests that we need a modified cultural transmission model, which increases the correlation between father and son, relative to brothers. Suppose that we have, as before,

$$y_{it} = z_{it} + u_{it} \qquad (12)$$

But now,

$$z_{it} = b(z_{it-1} + u_{it}) + e_{it} \; . \qquad (13)$$

The idea here is that any deviation in brother outcomes from that predicted by their family environment as children gets embedded in the environment of their children. Thus now the outcomes of children are more closely linked to their fathers than to their brothers. Now the correlation between father and son rises from $\theta b$ to b, while that between brothers remains at $\theta$. With the right parameters we can have $\theta = b$, so that the father and sibling correlations are the same.

However, while this model will capture this observed feature of social mobility, it fails completely to capture other significant features. One is that whatever the short run mobility rates is for any aspect of social status, the long run mobility is the same. Now the long run mobility rate has to equal that in the short run. So this crucial aspect of the social mobility process is missing.

## Other Tests of the Socio-Genetic Model

## Gender Symmetry

In this model despite their social disabilities in much of the period of the FOE database, such as barriers to formal education and employment, the socio-genetic model would predict that women play a symmetrical role with that of men in determining their childrens' social outcomes. The way we can empirically test for this is by looking at the predictive influence of the maternal and paternal grandfathers on grandchild outcomes, since for much of the period women did not have formal educational qualifications or occupations. To test for symmetry we can estimate the coefficients in the regression

$$y_c = a + b_f y_{gf} + b_w y_{gw} + e$$

where $y_c$ is the outcome for the grandson, $y_{gf}$ the outcome for the paternal grandfather, and $y_{gw}$ the outcome for the maternal grandfather. Table 5 shows the estimates.

**Table 7: The Comparative Influence of Paternal and Maternal Grandfathers**

| Grandchild Outcome | Paternal Grandfather | Maternal Grandfather | N | $R^2$ |
|---|---|---|---|---|
| Ln Wealth | 0.298*** | 0.105*** | 577 | 0.292 |
| | (.029) | (.030) | | |
| Occupational Rank | 0.346*** | 0.312*** | 2,509 | 0.498 |
| | (.018) | (.019) | | |
| Higher Education | 0.271*** | 0.289*** | 2,299 | 0.252 |
| | (.020) | (.020) | | |

As can be seen for wealth there is a distinctive asymmetry, where paternal lineage wealth is nearly three times as influential in predicting grandchild wealth as is maternal lineage wealth. But when we turn to occupational status or to attainment of higher education there is no difference in the predictive power of the paternal versus the maternal grandfathers. For these attributes women were just as important as men in predicting outcomes. This is consistent with the model where it was parental genetics which were the transmitters of social status.

**Genetics and Environment Interactions**

The assumption above that underlies the Fisher formula for the correlation of relatives that "*Genes and environment are uncorrelated, or the environment has little independent impact on outcomes*" would seem to be obviously violated in the case of social traits. The familial environment of families does clearly vary, and that variation will be correlated with the genetics that help determine family social status. However, there is good information from the *Families of England* database that the second part of the condition largely holds, and that family environments do indeed have *little independent impact on outcomes.*

The lineage used in this paper also allows us to test for the effects of elements of family environment on social outcomes, because for part of the period covered by the lineage, marriages 1780-1880, family size was largely random. In this period there was great variation in completed family size, numbers of children reaching age 21, with the size range in the sample for men ranging from 1 to 18. There was no correlation between family size and any measure of social status for fathers. There was also very weak correlation between brothers, and between fathers and sons, in terms of either births or completed family size. That correlation was in the range 0.03-0.05. Since brothers and fathers and sons correlate very strongly on an underlying latent variable for social status, which would correlate with lifestyles and choices on family size, this implies that both the number of births, and also childhood mortality, were mainly random in this interval, and not the product of individual decisions.

We just summarize the effects of the family size and birth order on social outcomes for marriages here, since we have another paper devoted to this substantial topic (Clark and Cummins, 2017). The families in the lineage can be separated into those lines where average wealth at death circa 1850 was high, and those where wealth at death then was average or non-existent. In the high wealth families servants anyway provided much of child care, so the effects of size might be expected to be less. In poorer families, this was a period where there was mostly no compulsory education. A legal requirement of school attendance to age 10 was only introduced in 1881. Thus in poorer families parents had to make an important decision about whether to support the children in schooling ages 11-20 that would be affected potentially by family size.

Table 6 summarizes the effect of family size, measured as either births (N0) or children reaching age 21 (N21) per father, on various social outcomes for marriages 1780-1879. Mostly results for sons are shown, except for the case of wealth at death, since in this period only sons have occupations and educational attainments. In each case the elasticity of the measure with respect to family size is given. In most cases there is a negative effect of size on outcomes. But if we look at adult outcomes – wealth at death, occupational status at age 40, attainment of higher educational qualifications, and child mortality for children – then only in the case of wealth are there significant effects, and here only for families from wealthy lineages. For occupational status, for example, the elasticities range from -0.03 to -0.09, implying that a 10% increase in family size reduces occupational status by 0.3%-0.9%.

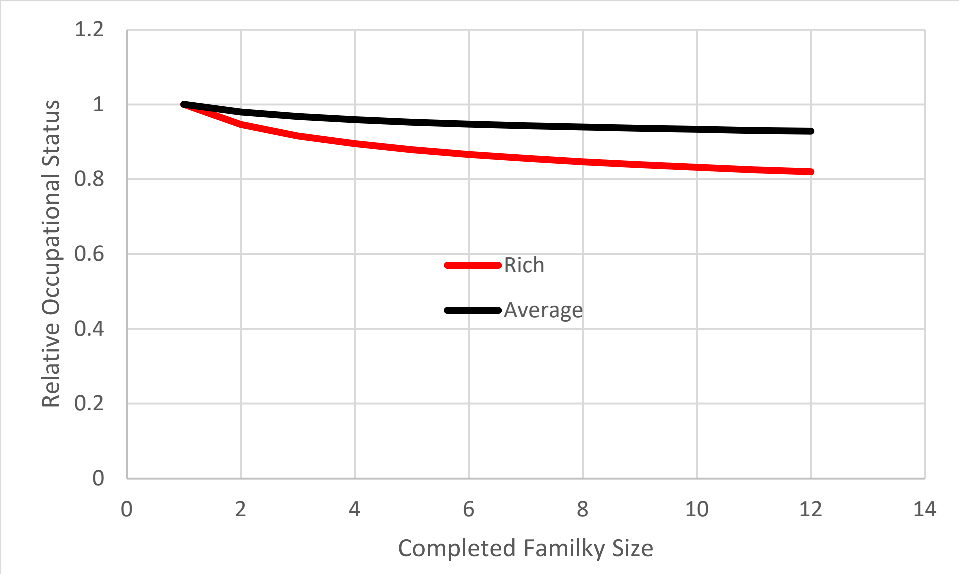
**Table 8: Elasticities of Outcomes with respect to Family Size, Marriages 1780-1879**

| Variable | Rich N0 | Rich N21 | Average N0 | Average N21 |
|---|---|---|---|---|
| At School 11-20, Boys | -0.07 | -0.05 | -0.24** | -0.13 |
| At School 11-20, Girls | -0.04 | -0.04 | -0.26** | -0.14 |
| Higher Education | -0.17** | -0.12* | 0.32 | 0.25 |
| Occupational Status | -0.09** | -0.08** | -0.05* | -0.03 |
| Child Survival, Children | 0.01 | 0.01 | -0.01 | 0.01 |
| Ln Wealth | -0.56** | -0.50** | -0.25** | -0.10 |

Note: *p<0.05, **p<0.01

To illustrate how modest are the size effects in Table 6 consider figure 12, which shows relative adult occupational status as a function of completed family size for average families, and for the families of the rich. For families in the lineages of average or poor social status expanding family size from 1 to 12 reduced the adult occupational status of children by 7%. For rich families the estimated effect was greater, an 18% reduction. But in both cases the overwhelmingly strong predictor of social outcomes was the social status of the father, not the numbers of children in the family.

**Figure 14: Family Size and Occupational Status of Children, marriages before 1880**




## Marital Assortment

We see above that marital assortment at the genetic level is key to explaining the substantial persistence of status across multiple generations if genes are the transmission mechanism. To explain the observed persistence the genetic correlation has to be 0.6 or greater. But all measures of marital assortment in terms of measurable characteristics suggest much less assortment. Table 9, for example, shows some estimates of the correlation of partners in marriage on observables. Even for years of education the observed correlation is only 0.50.

**Table 9: Phenotypic Correlations between Spouses**

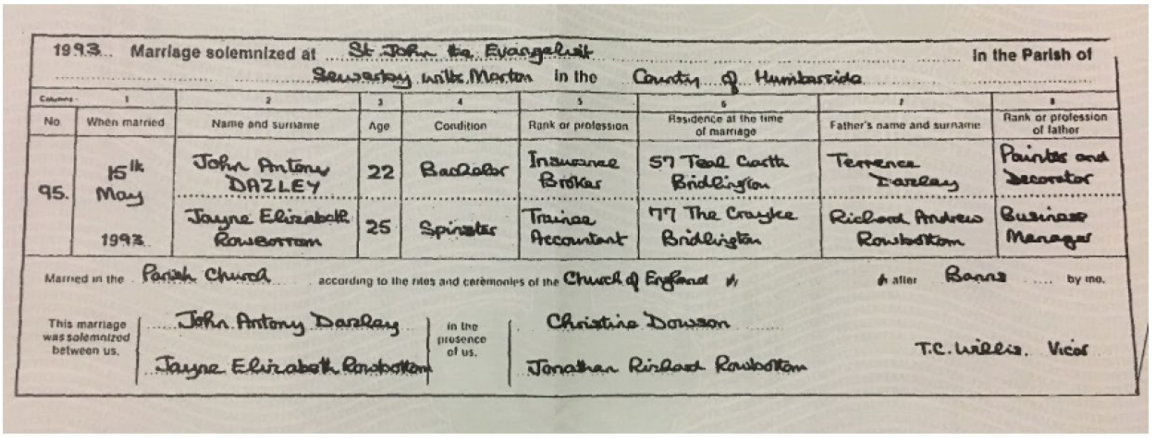
| Characteristics | Correlation | Source |
|---|---|---|
| Height | 0.29 | McManus and Mascie-Taylor, 1984 |
| Education | 0.50 | Watkins and Meredith, 1981 |
| Income | 0.34 | Watkins and Meredith, 1981 |
| Occupational Status | 0.12 | Watkins and Meredith, 1981 |
| IQ | 0.20-0.45 | Mascie-Taylor, 1989 |
| BMI | 0.28 | Abrevaya and Tang, 2011 |
| Personality Traits | 0.15 | Mascie-Taylor, 1989 |

However a recent study from the UK Biobank, which has a collection of genotypes of individuals together with measures of their social characteristics, supports the idea that there is strong genetic assortment in mating. Robinson et al., 2017 look at the phenotype and genotype correlations for a variety of traits – height, BMI, blood pressure, years of education - using data from the biobank. For most traits they find as expected that the genotype correlation between the parties is less than the phenotype correlation. But there is one notable exception. For years of education, the phenotype correlation across spouses is 0.41 (0.011 SE). However, the correlation across the same couples for the genetic predictor of educational attainment is significantly higher at 0.654 (0.014 SE) (Robinson et al., 2017, 4). Thus couples in marriage in recent years in England were sorting on the genotype as opposed to the phenotype when it comes to educational status.

It is not mysterious how this happens. The phenotype measure here is just the number of years of education. But when couples interact they will have a much more refined sense of what the intellectual abilities of their partner are: what is their general knowledge, ability to reason about the world, and general intellectual ability. Somehow in the process of matching modern couples in England are combining based on the weighted sum of a set of variations at several hundred locations on the genome, to the point where their correlation on this measure is 0.65.

We can empirically test for the idea that couples are matching on some underlying social and intellectual ability using an interesting set of data that has been created by a somewhat arbitrary act of Parliament back in 1837. This is the marriage certificate in England and Wales, which has been largely unchanged from 1837 to the present. An oddity of the marriage certificate is that it records the occupation of the bride and groom, as well as their fathers. Figure 13 shows an example of such a marriage certificate from 1993. Note that in the years before 1960 the occupation of the bride was most commonly left blank.

**Figure 15: Sample Marriage Certificate, 1993**


1993 Marriage solemnized at St John the Evangelist in the Parish of Sewerby with Marton in the County of Humberside

| Columns | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| No. | When married | Name and surname | Age | Condition | Rank or profession | Residence at the time of marriage | Father's name and surname | Rank or profession of father |
| 95. | 15th May 1993 | John Antony DAZLEY | 22 | Bachelor | Insurance Broker | 57 Teal Garth Bridlington | Terrence Dazley | Painter and Decorator |
| | | Jayne Elizabeth Rowbottom | 25 | Spinster | Trainee Accountant | 77 The Croyke Bridlington | Richard Andrew Rowbottom | Business Manager |

Married in the Parish Church according to the rites and ceremonies of the Church of England after Banns by me,

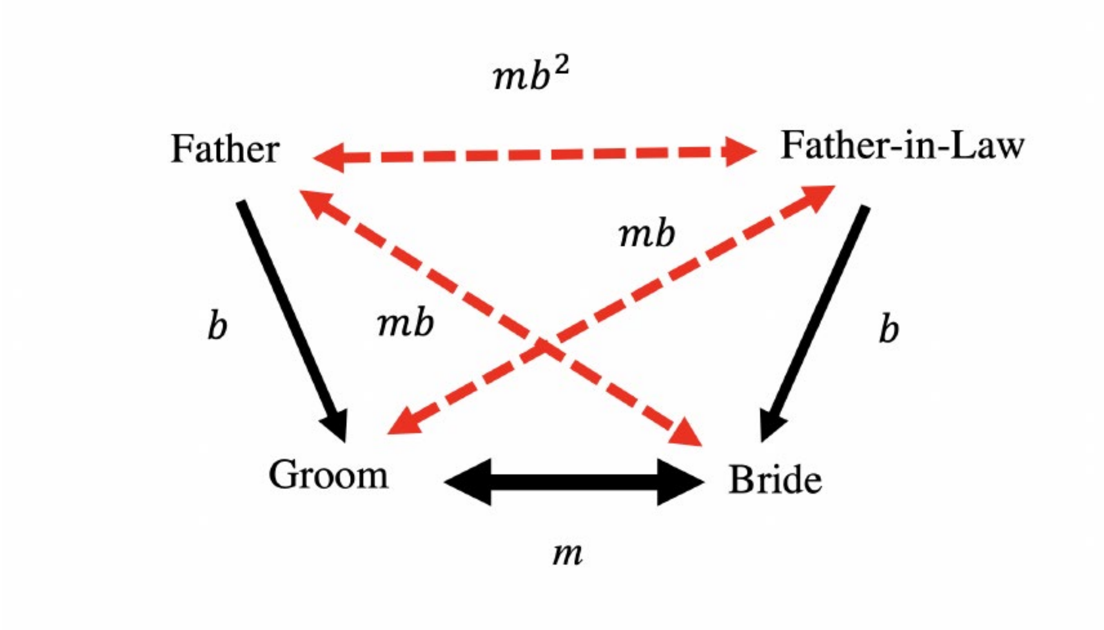
This marriage was solemnized between us. John Antony Dazley, Jayne Elizabeth Rowbottom — in the presence of us. Christine Dowson, Jonathan Richard Rowbottom — T.C. Willis. Vicar

For England and Wales the UK government holds copies of around 106 million such marriage records 1837-2021. However, it is both highly costly ($15) and very time consuming to obtain copies of these indices. Where, however, the marriage was performed in a church, a register of marriages was kept in the exact same form, and many of these registers have been deposited in local public record offices. An army of volunteers affiliated with the *Freereg* has transcribed around 1.6 million such marriage register entries for marriages 1837-2010.[7]

Suppose we assume that the parties in marriage are really combining based on underlying genetic characteristics which generate these occupational reports as a noisy signal of their underlying social abilities. What would the pattern of correlations between the parties look like? If we take $m$ as the correlation in genetics between the spouses, and $b$ as the genetic correlation between bride and groom and their fathers (where in equilibrium $b = \left(\frac{1+m}{2}\right)$ ), then the pattern of underlying genetic correlations will be as in figure 16. However, since the measures we observe are just an indictor of the underlying genotype, the observed occupational status of the parties will be correlated as in figure 17.

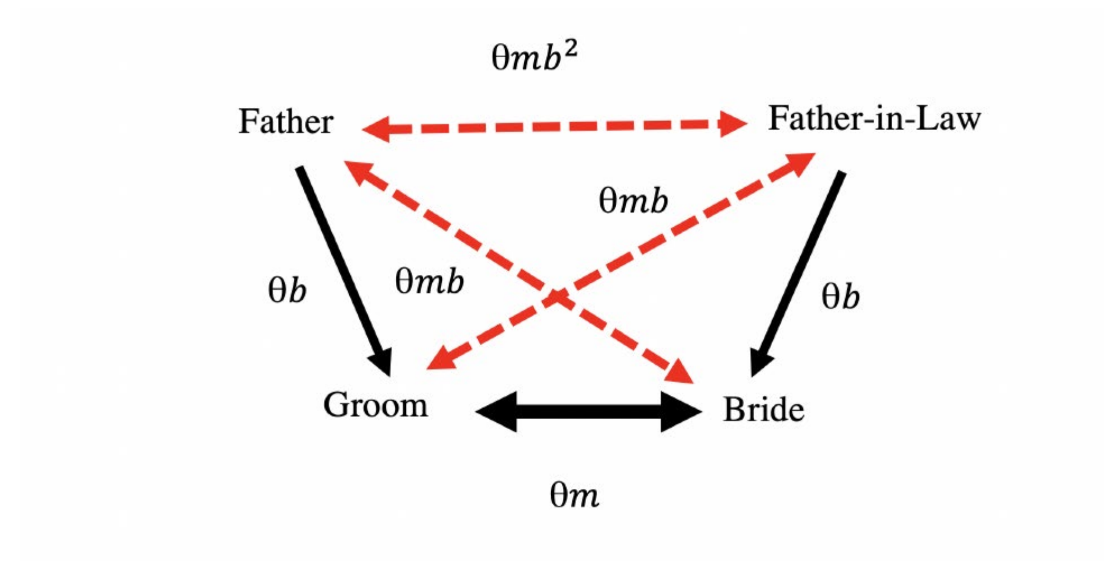
[7] https://www.freereg.org.uk/

**Figure 16: Underlying Correlation Pattern in Marriage**




Notes: the black lines show causal association, the red ones just correlations.

**Figure 17: Observed Correlation Pattern in Marriage**




Note: in the additive genetic interpretation of transmission, $\theta = h^2$.

Because we have imperfect measures of occupational status, and also because there is some randomness in attained status relative to underlying abilities, there will be measurement attenuation in all the observed correlations. This attenuation should be the same for all correlation pairs if occupations are observed at the same time.[8]

Figure 17 implies that we can estimate the true underlying correlation between bride and groom in occupational status just by dividing the groom's correlation in observed status with his father in law by the his correlation in observed status with his own father. Thus

$$m = \frac{correlation\ father{-}in{-}law\ to\ groom}{correlation\ father\ to\ groom} = \frac{\theta mb}{\theta b} \qquad (2)$$

If these occupational abilities are the product of additive genetics, then m would be the genetic correlation of the parties in marriage.

Similarly figure 17 suggests we can also get a measure of the true father-son correlation in occupational status b, from

$$b = \frac{correlation\ father{-}in{-}law\ to\ father}{correlation\ father{-}in{-}law\ to\ groom} = \frac{\theta mb^2}{\theta mb} \qquad (3)$$

The correlation between fathers and fathers-in-law will just be the product of the underlying correlation father-son (b), the underlying correlation son-wife (m), and the underlying correlation wife-father-in-law (b), multiplies always by the measurement attenuation factor $\theta$.

Table 10 displays those correlations by 40 years periods 1837-59, 1860-99, 1900-39, 1940-79, and 1980-2020. The surface data seems to suggest significant changes in intergenerational social mobility rates since the father-son and the father-in-law-son correlations in occupational status both decline significantly over time.

[8] Note, however, in table 10 the decline in all the familial correlations over time. This could be caused by more intergenerational social mobility in later years. Or it could just be because occupational labels are less descriptive of occupational status over time. But that could create a potential difference in the size of the measurement errors in the fathers' occupations versus the son's 30 years later.

**Table 10: Underlying Correlations in Occupational Status, marriages 1837-2020**

| Period | N | Father-Son | Father-in-law-son | Father-in-law-father | m | b |
|---|---|---|---|---|---|---|
| 1837-1859 | 379,945 | 0.723 | 0.585 | 0.541 | 0.81 | 0.92 |
| 1860-1899 | 492,996 | 0.680 | 0.561 | 0.520 | 0.82 | 0.93 |
| 1900-1939 | 205,473 | 0.588 | 0.478 | 0.439 | 0.81 | 0.92 |
| 1940-1979 | 43,350 | 0.403 | 0.325 | 0.300 | 0.81 | 0.92 |
| 1980-2020 | 4,034 | 0.327 | 0.248 | 0.183 | 0.76 | 0.74 |

Notes: Correlations calculated where the occupations of groom, father, and father-in-law all observed.

Table 10 shows the implied estimates of underlying marital assortment on social abilities between bride and groom for each period. These estimates are very high, implying a correlation of 0.8 or higher throughout the years 1837-1979 in the underlying social abilities of bride and groom. There is some chance that the correlation declined in the last 40 years, but the small numbers of observations in this period make that conclusion uncertain (the standard error on *m* in this period is 0.04, so there is no clear evidence that m differs from the 0.81 of earlier years). The estimate of the underlying father-son and father-daughter correlations of status are also very high being closer to 0.9.[9] These estimates may be distorted by the fact that the fathers and sons occupational status are measured at different points in the life cycle (in a way that does not influence the estimate of m). But they are actually quite consistent with the implication of the genetic model that $b = \left(\frac{1+m}{2}\right)$. If m = 0.8, then the expected value of b is 0.9. They also suggest again that social interventions in the latter part of the period 1837-2020 have not no effect on underlying assortment in marriage, or in

However, this creates something of a puzzle. Estimates from familial correlations in the genealogy suggest clearly values of *m* and *b* of 0.6 and 0.8. This is backed by genetic evidence for Britain on assortment in genetic educational potential in marriage again of 0.6.[10] However, here we are estimating even greater assortment, and even stronger persistence by looking at the correlation with inlaws.

[9] The standard error on the estimate of b in the last period is 0.076, so again the true value is potentially still 0.9 or close to this value.

[10] Another study not yet published finds this same correlation in the genetics underlying school years completed.

But the important point here is that the pattern of correlations between groom, father, and father-in-law on marriage certificates imply that the wedding records for England 1837-2020 imply that grooms and brides are actually matching very closely on underlying social capabilities all through the period 1837-2020. Thus there is nothing in the data that contradicts the possibility that marriage involved a close genetic match of partners in the genetics relevant to social outcomes. This creates a social world with an interesting connection between purely social practices, the nature of assortment in marriage, and biological facts, the importance of additive genetics in generating social outcomes.

## Conclusions

It is generally assumed that the elements that define social status – occupational status, educational attainment, wealth, and even health – are transmitted across generations in important ways by the family environment. Above we show that the patterns of correlation of social status attributes in an extended lineage of 410,000 people in England are mainly those that would be predicted by simple additive genetic inheritance of social status in the presence of highly assortative mating around status genetics. Parent-child correlations for a trait equal those of siblings, and the patterns of correlation of relatives of different degrees of genetic affinity is mainly consistent with that predicted by additive genetics. Further family size and birth order, elements that would significantly affect the family environment for children, have modest effects on adult outcomes. The underlying persistence of traits is such that people who have likely never interacted socially, such as second to fifth cousins, remain surprisingly strongly correlated in terms of occupational status and wealth. The patterns observed imply that marital sorting must be strong in terms of the underlying genetics.

If this interpretation is correct then aspirations that by appropriate social design, rates of social mobility can be substantially increased will prove futile. We have to be resigned to living in a world where social outcomes are substantially determined at birth.

# Data Sources

### Births, Deaths, Marriages

General Register Office. England and Wales Civil Registration Indexes. London, England: General Register Office.

FreeBMD. England & Wales, FreeBMD Death Index: 1837-1915 [database on-line]. Provo, UT, USA: Ancestry.com Operations Inc, 2006. Available at www.ancestry.com (last accessed: 01 Apr 2016).

FreeBMD. England & Wales, FreeBMD Birth Index, 1837-1915 [database on-line]. Provo, UT, USA: Ancestry.com Operations Inc, 2006. Available at www.ancestry.com (last accessed: 01 Apr 2016).

Ancestry.com. England & Wales, Birth Index: 1916-2005 [database on-line]. Provo, UT, USA: Ancestry.com Operations Inc, 2008. Available at www.ancestry.com (last accessed: 01 Apr 2016).

Ancestry.com. England & Wales, Death Index: 1916-2006 [database on-line]. Provo, UT, USA: Ancestry.com Operations Inc, 2007. Available at www.ancestry.com (last accessed: 01 Apr 2016).

Ancestry.com. Public Member Trees [database on-line]. Provo, UT, USA: www.ancestry.com Operations. Inc., 2006. Original data: Family trees submitted by Ancestry members.

### Social Outcomes

Censuses, 1841-911 and Population Register 1939

England and Wales, Censuses, 1841-1901. Available online at http://www.nationalarchives.gov.uk/records/census-records.htm.

England and Wales, Population Register, 1939. London, UK. 1939 Original Data: 1939 Register, 1939. Kew, Surrey, England: The National Archives of the UK (TNA). Available at http://www.findmypast.com/1939register.

### Wealth at Death

England and Wales, Index to Wills and Administrations, 1858-2012. Principal Probate registry, London (available online 1858-1966 at Ancestry.co.uk).

Gov.UK. Wills and Probate 1858-1996 [database on-line]. Original data: Principal Probate

Registry. Calendar of the Grants of Probate and Letters of Administration made in the Probate Registries of the High Court of Justice in England. London, England © Crown copyright. Available at https://probatesearch.service.gov.uk/Calendar#calendar (last accessed: 01 Apr

2016).
General Register Office. 1861. Annual Report of the Registrar General 1859. (pp. 173-181) Available online at http://www.histpop.org (last accessed: 01 Apr 2016).
Prerogative Court of Canterbury and Related Probate Jurisdictions: Probate Act Books. Volumes: 1850-57. Held at the National Archives, Kew. (Catalogue Reference: PROB 8/243-250.)

**Educational Status**

Ancestry.com. UK, Articles of Clerkship, 1756-1874 [database on-line]. Provo, UT, USA: www.ancestry.com Operations, Inc., 2012. Original data: Court of King's Bench: Plea Side: Affidavits of Due Execution of Articles of Clerkship, Series I, II, III (KB 105-107). The National Archives, Kew, Richmond, Surrey. Registers of Articles of Clerkship and Affidavits of Due Execution (CP 71). The National Archives, Kew, Richmond, Surrey. Available at www.ancestry.com(last accessed: 01 Apr 2016).
Ancestry.com. Cambridge University Alumni, 1261-1900 [database on-line]. Provo, UT, USA: Ancestry.com Operations Inc, 1999. Original data: Venn, J. A., comp.. Alumni Cantabrigienses. London, England: Cambridge University Press, 1922-1954. Available at www.ancestry.com (last accessed: 01 Apr 2016).
Ancestry.com. Oxford University Alumni, 1500-1886 [database on-line]. Provo, UT, USA: Ancestry.com Operations Inc, 2007. Original data: Foster, Joseph. Alumni Oxonienses: The Members of the University of Oxford, 1715-1886 and Alumni Oxonienses: The Members of the University of Oxford, 1500-1714. Oxford: Parker and Co., 1888-1892. Available at www.ancestry.com (last accessed: 01 Apr 2016).
Ancestry.com. UK, Crockford's Clerical Directories [database on-line]. Provo, UT, USA: Ancestry.com Operations Inc, 2009. Original data: Crockford Clerical Directory. England: 1868-1932. See title page image of each directory for original source information. Available at www.ancestry.com (last accessed: 01 Apr 2016).
Ancestry.com. UK, Electrical Engineer Lists, 1871-1930 [database on-line]. Provo, UT, USA: Ancestry.com Operations, Inc., 2014. Original data: Society of Telegraph Engineers (later, Institution of Electrical Engineers) Membership Lists, 1887–1930. Institution of Engineering and Technology, Savoy Place, London, England. UK, Civil Engineer Lists, 1818-1930. Available at www.ancestry.com (last accessed: 01 Apr 2016).
Ancestry.com. UK, Mechanical Engineer Records, 1847-1930 [database on-line]. Provo, UT, USA: Ancestry.com Operations, Inc., 2013. Original data: Mechanical Engineering Records, 1847-1930. London, UK: Institution of Mechanical Engineers. Available at v (last accessed: 01 Apr 2016).
Ancestry.com. UK Medical Registers, 1859-1959 [database on-line]. Provo, UT, USA: Ancestry.com Operations Inc, 2008. Original data: General Medical Council, comp.

UK Medical Registers, 1859-1959. London: General Medical Council, 1859-1959. This data is provided in partnership with the General Medical Council. Available at www.ancestry.com (last accessed: 01 Apr 2016).

Royal Military Academy Sandhurst. The Sandhurst Collection [database on-line]. Available at http://archive.sandhurstcollection.co.uk/ (last accessed: 01 Apr 2016).

Senate House Library, University of London. 2016. University of London Students 1836-1934 [database on-line]. Available at http://www.senatehouselibrary.ac.uk/our-collections/special-collections/archives-manuscripts/university-of-london-students-1836-1934 (last accessed: 01 Apr 2016).

**Bibliography**

Abrevaya, J and H. Tang. 2011. "Body mass index in families: spousal correlation, endogeneity, and intergenerational transmission." *Empirical Economics, 41*: 841–864.

Becker, Gary S., and Tomes, Nigel. "An Equilibrium Theory of the Distribution of Income and Intergenerational Mobility." *J.P.E.* 87 (1979): 1153–89.

Becker, Gary S., and Tomes, Nigel. "Human Capital and the Rise and Fall of Families." *J. LaborEcon.* 4, no.3, pt.2 (1986): S1–S39.

Clark, Gregory. 2017. "Estimating Social Mobility Rates from Surnames: Social Group versus Family Effects." Working Paper, March.

Clark, Gregory and Neil Cummins. 2017. "The People, not the Place. The Decline of the North of England 1918-2017: A Surname Investigation." Working Paper, February.

Clark, Gregory and Neil Cummins. 2016. "Family Matters? Do Relatives other than Parents Matter to Social Outcomes, England 1780-2016?" Working Paper, November.

Clark, Gregory and Neil Cummins. 2016. "The Child Quality-Quantity Tradeoff, England, 1780-1880: A Fundamental Component of the Economic Theory of Growth is Missing." Working Paper, August.

Clark, Gregory and Neil Cummins. 2015. "Intergenerational Wealth Mobility in England, 1858-2012. Surnames and Social Mobility." *Economic Journal, 125*(582): 61-85.

Clark, Gregory and Neil Cummins. 2014. "Surnames and Social Mobility: England, 1170-2012." 2014. *Human Nature, 25*(4), 517-537.

Clark, Gregory, Cummins, Neil et al. 2014 *The Son Also Rises: Surnames and the History of Social Mobility.* Princeton: Princeton University Press.

Clemons, Traci. 2000. "A Look at the Inheritance of Height Using Regression toward the Mean." *Human Biology, 72*(3): 447-454.

Falconer, D. S. 1981. *Introduction to Quantitative Genetics.* 2nd ed. London: Longman.

Fisher, R. A. 1918. "The Correlation between Relatives on the Supposition of Mendelian Inheritance." *Transactions of the Royal Society of Edinburgh, 52:* 399-433.

Galton, Francis, "Typical laws of heredity," *Proceedings of the Royal Institution of Great Britain*, 1877, 8, 282–301.

Goldberger, Arthur, "Economic and mechanical models of intergenerational transmission," *American Economic Review*, 1989, 79 (3), 504–513.

Hill, William G., Michael E. Goddard, and Peter M. Visscher. 2008. "Data and Theory Point to Mainly Additive Genetic Variance for Complex Traits." Plos Genetics, 4(2), e1000008.

Holt, Sarah B. 1961. "Quantitative Genetics of Fingerprint Patterns." *British Medical Bulletin*, 17: 247-50.

Mascie-Taylor, C. G. Nicholas. 1987. "Assortative mating in a contemporary British population." *Annals of Human Biology*, *14*:1: 59-68. DOI: 10.1080/03014468700008841

Mascie-Taylor, C. G. N. 1989. "Spouse Similarity for IQ and Personality and Convergence." *Behavior Genetics, 19(2)*: 223-7.

McManus, I. C. and C. G. N. Mascie-Taylor. 1984. "Human Assortative Mating for Height: Non-Linearity and Heteroscedasticity." *Human Biology, 56(4)*: 617-623.

Mulligan, Casey, "Galton versus the human capital approach to inheritance," *Journal of Political Economy*, 1999, 107 (S6), S184–S224.

Nagylaki, Thomas. 1978. "The correlation between relatives with assortative mating." *Annals of Human Genetics, 42*: 131.

Plomin, R 2011. "Commentary: Why are children in the same family so different? Non-shared environment three decades later." *International Journal of Epidemiology* 40: 582–592.

Plomin, R., Fulker, D.W., Corley, R., and DeFries, J. C. 1997. "Nature, nurture, and cognitive development from 1-16 years: A parent-offspring adoption study." *Psychological Science*, *8*: 442-447.

Robinson, Matthew R., et al., 2017 "Genetic evidence of assortative mating in humans," *Nature Human Behaviour*, 2016, 1. Article number: 0016 (2017).

Sacerdote, Bruce. 2007. "How Large Are the Effects from Changes in Family Environment? A Study of Korean American Adoptees." *Quarterly Journal of Economics, 122*(1): 119-157.

Silventoinen, Karri, Jaakko Kaprio, Eero Lahelma, Richard J. Viken, and Richard J. Rose. 2003. "Assortative Mating by Body Height and BMI: Finnish Twins and Their Spouses." *American Journal of Human Biology 15*:620–627.

Solon, Gary. "Intergenerational mobility in the labor market," in Orley Ashenfelter and David Card, eds., *Handbook of Labor Economics* Volume 3A, 1999, pp. 1761–1800.

Tambs, Kristian, Torbjørn Moum, Lindon J. Eaves, Mike C. Neale, Kristian Midthjell, Per G. Lund-Larsen and Siri Næss. 1992. "Genetic and Environmental Contributions to the Variance of Body Height in a Sample of First and Second Degree Relatives." *American Journal of Physical Anthropology 88: 285-294.*

Watkins MP, Meredith W. 1981. "Spouse similarity in newlyweds with respect to specific cognitive abilities, socioeconomic status, and education." *Behavior Genetics, 11(1)*: 1-2.