The Contribution of Skills and Family Background to Educational Mobility*

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Abstract
We study the role of hard and soft skills in economic performance and social mobility in a sample of twins (N = 2,764) from the Minnesota Twin Family Study, combining classical economic models of parental investment with a complete and realistic equilibrium model of genetic transmission of skills. Hard and soft skills have comparable roles in affecting early educational success and college attainment. We then use the information on family background to estimate the determinants of social intergenerational mobility. The transmission of personality characteristics – in particular but not exclusively of intelligence – explains a substantial fraction of upward and downward mobility of children.

Keywords: Genetics; inequality; mobility; soft and hard skills
JEL classification: D9; J1; J24

I. Introduction
The contribution of cognitive factors to academic success has been extensively investigated and convincingly established. Intelligence and other cognitive abilities are strongly associated with both doing well academically and the ultimate level of educational attainment (Strenze, 2007; Deary, 2012). Recently, a convergence of findings across multiple programs of research has drawn attention to the role non-cognitive factors might play in educational outcomes. Perhaps most prominent among these is the

*We thank two referees for detailed comments on an earlier draft of the paper. Supported in part by grants from the National Science Foundation (SES1357877), the National Institute on Alcohol Abuse and Alcoholism (AA09367), and the National Institute of Drug Abuse (DA05147).

Skills and family background

reanalysis of the landmark Perry Preschool program by Heckman and colleagues, who reported that individuals who received the preschool intervention had higher levels of educational attainment, employment, and marriage, and lower levels of crime, as adults than individuals who did not receive the intervention (Heckman and Kautz, 2012). However, the Perry program was not associated with enduring increases in measured intelligence, suggesting that the long-term intervention effects might be a result of non-cognitive rather than cognitive factors. In support of this interpretation, Heckman et al. (2013) have shown that the Perry intervention was associated with lower levels of externalizing behavior and higher levels of academic initiative, although the effect on the latter was seen only in females.

Further support for the importance of non-cognitive factors comes from a growing body of research showing that personality factors are associated with academic and related outcomes. Much of this research has been based on the five-factor model of personality (Goldberg, 1993) and has implicated conscientiousness as the personality factor most strongly associated with academic outcomes. Meta-analyses have shown that conscientiousness is moderately associated with academic success at both elementary school (Poropat, 2014) and university (Poropat, 2009) levels. These findings with academic outcomes parallel meta-analytical findings with work outcomes, which also identify conscientiousness as the strongest predictor among the big-five traits (Barrick and Mount, 1991). Finally, research by Duckworth and her colleagues further supports an important contribution of non-cognitive factors to academic outcomes. In a series of short-term longitudinal studies with middle-school students, these researchers have shown that both cognitive and non-cognitive factors contribute to academic success, with non-cognitive factors sometimes carrying more predictive weight than cognitive factors (Duckworth and Seligman, 2005; Duckworth et al., 2007). Duckworth believes that the key non-cognitive factor is what she calls “grit”, a multifaceted construct that represents a combination of self-control, perseverance, and interest. Individuals with high levels of grit are capable of postponing immediate rewards in the service of achieving long-term goals (Duckworth et al., 2007). While Duckworth has stated that grit is conceptually distinct from conscientiousness, there appears to be a strong empirical overlap between the two. A popular self-reported measure of grit correlated 0.77 with the conscientiousness scale from the big-five inventory (Duckworth et al., 2009).

The research described here addresses several key unanswered questions about the relationship between cognitive and non-cognitive factors and academic outcomes. First, the existing research is predominantly cross-sectional or involves short-term longitudinal follow-up (e.g., within the same school year). Apart from the Perry program, relatively little is known
about the long-term contributions of cognitive and non-cognitive factors assessed in childhood and adolescence to social outcomes in adulthood. Second, the relationship between non-cognitive factors and family background is largely unaddressed by the existing body of literature. Cognitive ability is known to be moderately associated with family background (White, 1982), suggesting that one of the advantages of highly educated parents is that they are likely to transmit to their children (either through genetic or environmental mechanisms) the cognitive skills needed for academic success. However, it is not clear whether highly educated parents are also able to transmit the relevant non-cognitive skills to their children.

Research Questions

The present study uses longitudinal observations on a sample of 2,764 twins, first assessed in adolescence and followed through early adulthood, to address the following research questions. What are the individual and combined contributions of cognitive skills, non-cognitive skills, and family background to educational success and social outcomes later in life? How do cognitive and non-cognitive factors contribute to both upward and downward educational mobility within families, and how do the genetic factors, parental investment decisions, and family environment separately affect mobility?

To address these questions, we set up a well-specified model of skill formation, and consequently of income determination. The model we use is an extension of the classical Becker and Tomes (1979) model, as reformulated by Solon (2004), to include a detailed model of skill transmission. Parental investment in the education of their children is obtained as the optimal solution of a consumption and investment decision of altruistic parents. In the log specification we use (as in Solon, 2004), the solution assigns to investment a constant fraction of parents’ income. In the commonly used version of parental investment, the model is closed by assuming a skill transmission from a representative parent of unspecified gender, and is assumed to follow an AR(1) process (as in the original Becker–Tomes model). We modify this, formulating instead a skill transmission model that makes explicit the separate contributions of genetic transmission from both parents and of the cultural and social background (through parental investment and the externality of the family environment).

There are several reasons to do this. The first reason is that we need to make explicit the difference in the joint distribution of skill between monozygotic (MZ) and dizygotic (DZ) twins, being able to do so even conditionally on the information on parents’ skills and income. We use this property in our estimations, particularly in Section VII, Determinants of Hard and Soft Skills. In this way, the model is also different from the
standard ADCE decomposition of variance of phenotypes widely used in behavioral genetics (Boker et al., 2011), and widely used in economic analysis of twins; see the literature reviewed in Section 2 of Black and Devereux (2011). The second reason is that we want to explicitly model the contribution of observable environmental variables, in particular family income and education of the parents. A third reason is that, in this way, the model is ready for the extension of the analysis to explicit consideration of factors such as the nature of the assortative matching of parents. Finally, the model as stated can now be tested using information on the genotype of the individuals (parents and twins), information that is already available for the Minnesota Twin Family Study (MTFS) sample, which has been genotyped on several hundred thousand genetic markers. The reason we chose not to use the information on genotype at this stage is that the nature of the function mapping genotype to the genetically determined component of the skill is not yet clear; this is the topic of forthcoming research. The model of genetic transmission follows well-established rules; it allows also a greater generality, compared to the AR(1) formulation and its variations. An important difference is that the model of parental investment in Section II, with an optimal linear policy, augmented by a linear skill transmission (as, for example, equation (2.3) in Solon, 2004), has a normal invariant distribution. With a precise model of genetic transmission, even the single peak property of the invariant distribution is lost. However, the model introduces further discipline and predictive power: for example, the model provides prediction on possible deviations from the Hardy–Weinberg equilibrium of the distribution of the genotype.

II. Equilibrium Model of Parental Investment and Genetic Transmission

The data (described in detail in Section IV) include information on skills of both types for parents and children; in addition, children are twins, both MZ and DZ. This information allow us to examine the role of cultural (and parental investment) and genetic transmission of these skills, and to disentangle the two. The model we formulate now will allow us to do this in a precise way. The model has two parts: the first is the standard parental investment decision, and the second is the intergenerational skill transmission. We begin with the first.

Parental Investment

The family maximizes a utility function of own consumption and future income of the (in our case) two children, which is affected by the parental investment in education. Let $y$ denote the natural log of income,
Let \( E \) consumption expenditure, \( I \) parental investment in education of children, and \( e \) education level. Let \( \epsilon^e \) and \( \epsilon^y \) denote the random shock to education and income, independent and identically distributed (i.i.d.) in every period and across periods. Let \( \eta \in [0, 1], \alpha, \lambda \) denote positive real numbers. The vector of all skills is \( \theta = (\theta^1, \ldots, \theta^n, \theta^{n+1}, \ldots, \theta^m) \), where a subset (i.e., those with index from 1 to \( N_h \)) refers to hard skills, and those from \( N_h + 1 \) to \( N \) refer to soft skills. Skills enter linearly into the production of the education level with a vector of coefficients \( \rho \). The subscript \( i \) refers to the family, \( j = 1, 2 \) to the twin; so a twin is uniquely identified by the pair \( ij \).

Household log-income \( y_i \) is some combination of the log-income of the father \( y^f_i \) and mother \( y^m_i \). The specific form of the combination depends on the matching process that we describe later in Section II, Matching Processes. The parental investment is a household investment.

The family maximizes

\[
\max_{(E_i, I_{i1}, I_{i2})} E(\theta_i, \theta_{i2}) \left[ (1 - \eta) \ln E_i + \eta \sum_{j=1,2} y_{ij} \right],
\]

subject to

\[
E_i + \sum_{j=1,2} I_{ij} = \exp(y_i) \equiv Y_i,
\]

\[
e_{ij} = \alpha \ln I_{ij} + \rho \theta_{ij} + \epsilon^e_{ij}, \quad j = 1, 2,
\]

\[
y_{ij} = \lambda e_{ij} + \epsilon^y_{ij}, \quad j = 1, 2.
\]

The expectation in equation (1) is taken with respect to the information the family \( i \) has at the moment of deciding the educational investment. This information is likely to include some knowledge of the skills \((\theta_{i1}, \theta_{i2})\) of the children, although perhaps not of the random shocks \( \epsilon^e_{ij}, j = 1, 2 \) and \( \epsilon^y_{ij}, j = 1, 2 \).

The optimal solution of the problem in equations (1)–(4) has optimal parental investment equal for the two siblings \( \hat{I}_{i1} = \hat{I}_{i2} \equiv \hat{I}_i \), and a constant fraction of household income \( \exp(y_i) \):

\[
\hat{I}_i = \frac{\alpha \eta \lambda}{2 \alpha \eta \lambda + 1 - \eta} \exp(y_i) \equiv \psi \exp(y_i).
\]

The model is relying on some restrictive assumptions and simplifications. It does not allow for unobserved skills; it also does not include gene × environment interactions. Although these are important considerations, the lack of any useful data in our sample suggested that we ignore them for the moment. We assume that the family plans conditional on having
two children, an event known at the moment of the planning; hence the choice of the sum over the utility from the two incomes of the children. However, we ignore other children in the family. The fact that the parental investment is equal for the two children, even if the level of hard and soft skills is different, is strictly speaking a conclusion and not an assumption. This is important in our context, because the larger similarity of the MZ twins in the realization of the genotype conditional on the genotype of the parents might in general induce a more similar behavior of parents than for DZ twins. This implication would make the conclusion (used in Section II, *Skill Transmission*), that the effect of family income is independent of the twin type, false. It is true that this conclusion holds only because of the very specific functional form of the utility of the family. In a more general formulation, this would not be true, and some of the criticisms of the biometric literature on twins, such as the Goldberger critique (see, for example, Goldberger, 1979; Kamin and Goldberger, 2002), should then be taken into account, and the effect size of the parental response to the information on the skills of their children should be estimated.

*Skill Transmission*

The model we have described so far is standard. We have only introduced some minor modification, in particular the introduction of the distinction between hard and soft skills, to match the data we have, and to address the main question of the paper. Instead, to the best of our knowledge, the model of skill transmission is new; we have discussed in the Introduction the motivation to introduce this detailed model.

We take the $k$th skill $\theta^k$ to be the result of a combination of purely genetic factors, of parental investment, of family environment common to all children, and of idiosyncratic random events for each individual. In the following, to lighten notation we drop the index $k$ of the skill. Let us begin with the genetic component. If $K$ is the finite number of alleles affecting the skill, then a genotype is a $g \in G^K \equiv \{0, 1, 2\}^K$. Let the function $w$ describe the component of the phenotype that is determined by the genotype $g_{ij}$, let $r$ denote a positive number scaling the importance of $w$ (this parameter is redundant, but will be convenient when estimating the effect of the genotype), let $X$ denote a vector of observable variables (which include, for instance, the parents’ education, the family income and social status, etc.), let $C$ denote a family specific shock (common to both twins, either MZ or DZ), and let $\epsilon_{ij}^\theta$ denote an individual specific environmental shock.

The skill phenotype of twin $ij$ is given by

$$\theta_{ij} = rw(g_{ij}) + X_{ij} \Pi + C_i + \epsilon_{ij}^\theta.$$  

(6)
The joint distribution of genotypes of the children, given the genotype of the two parents, depends on the twin type (MZ or DZ). To define it, we start with the genetic transmission from parents’ genotype to the probability over genotypes of an individual offspring, described by a function $M$:

$$M : (g^m, g^f) \mapsto M(g^m, g^f) \in \Delta(G^K).$$  \hspace{1cm} (7)

$M$ follows well-known rules; for instance, if $K = 1$, so $G = \{0, 1, 2\}$, then $M(1, 1)$ is $(0.25, 0.5, 0.25)$. Note that $M$ is weakly increasing separately in each component $g^m$ and $g^f$, when $G^K$ has the natural component-wise partial order, and $\Delta(G^K)$ is endowed with the first-order stochastic dominance partial order.

For twins, the functions $M_T(g^m, g^f) \in \Delta(G^K \times G^K)$, for $T \in \{DZ, MZ\}$ are defined as

$$M_{DZ}(g^m, g^f)(g^1, g^2) = M(g^m, g^f)(g^1)M(g^m, g^f)(g^2)$$  \hspace{1cm} (8)

and

$$M_{MZ}(g^m, g^f)(g^1, g^2) = M(g^m, g^f)(g^1) \text{ if } g^1 = g^2$$

$$= 0 \text{ otherwise.}$$  \hspace{1cm} (9)

**Reduced Model**

We consider first the simplified model where the only observable variable in the vector $X$ in equation (6) is parental income, so $X_{ij} = y_i \pi$, and equation (6) becomes

$$\theta_{ij} = rw(g_{ij}) + \pi y_i + C_i + \epsilon_{ij}.$$  \hspace{1cm} (10)

In the analysis below, we also use the more general model to control for education of parents, college degree of parents, and work status of the father. Substituting the optimal investment determined by equation (5) into equation (3) and substituting the result into equation (4), we obtain the reduced equation for income $y_{ij} = a + \beta y_i + \gamma \theta_{ij} + \lambda \epsilon_{ij}$ with $a = \alpha \lambda \ln \psi$, $\beta = \alpha \lambda$ and for every $k$, $\gamma^k = \rho^k \lambda$.

The complete model of the process on genotype, income, education, and skill for twins of type $T$ is given by equation (3) for education, equation (6) for skill, equations (8) and (9) for the genotype transmission, and the above reduced equation for income. We assume

$$\beta + \gamma \pi < 1.$$  \hspace{1cm} (11)

The genotype and income process alone determine completely the equilibrium. Note first that, because of the assumption (11), the system has an
invariant distribution $\mu \in \Delta(G^K \times Y)$. We can then subtract from the variables $[y_{ij}, \theta_{ij}, e_{ij}, w(g_{ij})]$ their expected value with respect to the invariant distribution; so the constants are eliminated (e.g., the $a$ term in the reduced equation for income is eliminated). Because no confusion is possible, we keep the same names for these variables, which have now zero mean. We write equations (8) and (9) in the compact form:

$$g_{ij} \sim M_T(g^m_{ij}, g^f_{ij}), \quad T \in \{MZ, DZ\}. \quad (12)$$

If we substitute equation (10) into the reduced equation for income, we obtain

$$y_{ij} = (\beta + \gamma \pi)y_i + \gamma r w(g_{ij}) + \gamma C_i + \gamma \epsilon_{ij}^\theta + \epsilon_{ij}^\gamma. \quad (13)$$

Note that in equation (13) we have absorbed the term $\lambda \epsilon_{ij}^e$ into $\epsilon_{ij}^\gamma$. We do the same for equation (15).

Equations (12) and (13) completely determine a non-linear – because of equation (12) – transition on measures on the space of genotypes and income, $\Delta(G^K \times Y)$, when we specify how the pairs of parents are selected. This is done in the following subsection, Matching Processes. For a pair $(y_{ij}, g_{ij})$, we can then compute skills with equation (10) and education (after elimination of the constant) with

$$e_{ij} = \alpha y_i + \rho \theta_{ij} + \epsilon_{ij}^e. \quad (14)$$

An equivalent system, which is more convenient for estimation, has equations (10), (12), and

$$y_{ij} = \beta y_i + \gamma \theta_{ij} + \epsilon_{ij}^\gamma. \quad (15)$$

Finally, we assume:

$$E_{\epsilon_{ij}}^k = 0, k \in \{\theta, y, e\}; \quad E_{\epsilon_{ij}}^k \epsilon_{ij}^l = 0, \quad k, l \in \{\theta, y, e\}, k \neq l; \quad (16)$$

$$E C_i \epsilon_{ij}^k = 0, k \in \{\theta, y, e\}. \quad (17)$$

Matching Processes

The system of equations (12) and (13) or alternatively equations (10), (12), and (15) are complete if we specify the matching process for parents. A matching process associates to the distribution $\mu$ a new distribution $M(\mu) \in \Delta((G^K \times Y)^2)$, describing the distribution of pairs $(g^m_{ij}, g^f_{ij}, y^m_{ij}, y^f_{ij})$ of genotypes and income of the two parents. We require the pairs of parents to have the same distribution as the original $\mu$, that is $M(\mu)(\cdot \times G^K \times Y) = M(\mu)(G^K \times \cdot \times Y) = \mu(\cdot)$. We consider two examples: random matching and assortative matching on income. In both cases, the process determines an invariant distribution, obviously different in the two cases, with different
implications for inequality in income distribution, mobility, and association between genotype and other variables.

With random matching, a pair \((g^m, y^m)\) of genotype and income is selected for the mother, and independently a pair \((g^f, y^f)\) for the father, according to \(\mu\). In equations (13) and (15), we can then set the household log-income \(y_i = 0.5(y^m + y^f)\). This model is convenient for its simplicity, but it is not supported by the data, which show instead substantial positive correlation between several characteristics of the parents. Thus, a model with positive assortative matching is a better approximation (although not literally true).

With perfect assortative matching on income, first an income level \(y\) is determined according to the marginal \(\mu_Y\) on income. Matching then occurs randomly within the population of prospective parents with this income: a pair \((g^m, g^f)\) of genotypes for father and mother are determined according to the conditional probability \(\mu(\cdot|y)\). The distribution of genotypes of children in the \(y\)-population is in Hardy–Weinberg equilibrium, with respect to the distribution of allele frequencies induced by \(\mu(\cdot|y)\). In equations (13) and (15), \(y_i\) is equal to the level of income common to \(m\) and \(f\). In both cases, equations (10) and (14) then determine the corresponding values of education and skills.

III. From Model to Estimation

The system of equations (10), (12), and (15) is more complex than equations (12) and (13), but more suitable to discuss the estimation strategy. For a family \(i\), the vector of observed data is \([\theta^m_i, \theta^f_i, y_i, y^f_i, (\theta_{ij}, y_{ij})_{j=1,2}, T(i)]\), describing the skills of the mother and the father, household income, the skill of the two offspring, and the twin type \((T(i) \in \{MZ, DZ\})\). Unobserved variables that are part of the model are parents’ genotypes, parents’ original family income, and twins’ genotypes: \([g^m_i, g^f_i, y_{F(m)}, y_{F(f)}, (g^i_{ij})_{j=1,2}]\), where \(F(m)\) is the mother’s original family. We have equations (10) and (15) for the father and the mother, which we can use to make inference on some property of the distribution of \((g^m_i, g^m_i)\), eliminating the parents’ original family income. Note that we now reintroduce the index \(k\) for the specific skill that had been dropped at the beginning of the subsection Skill Transmission in Section II. Simple algebra gives the purely genetic component of the \(k\)th skill of the mother, denoted by \(w(g^{k,m})\), as

\[
w(g^{k,m}) = \frac{\theta^{k,m}}{r^k} - \frac{\pi}{r^k \beta} y^m + \frac{\pi}{r^k \beta} y' \theta^m + \frac{\pi}{r^k \beta} \epsilon^y - \frac{C_{F(m)} + \epsilon^k}{r^k}. \tag{18}
\]

If we assume perfect assortative matching in income, we obtain \(y_{ij} = y^m = y^f\); then, using equation (18), we can estimate the genetic and
environmental transmission of a skill by a linear mixed effects regression:

$$\theta_{ij}^k = \beta_m \theta_m^i + \beta_f \theta_f^i + \eta^k y_i + Z_i^{k,T} + C_i^k + \epsilon_{ij}^\theta.$$

(19)

Here, from the properties of our model, we anticipate:

(1) the random variable

$$Z_{i,T}^k \sim N(0, \sigma_k^2 \Sigma^T),$$

where $\Sigma^T$ is the $2 \times 2$ identity matrix if $T = DZ$ and the $2 \times 2$ matrix of ones if $T = MZ$;

(2) $\beta_m$ and $\beta_f$ are positive and equal;

(3) the effect of family income $\eta^k$ is of ambiguous sign because it is the sum of a positive term (described by $\beta$ in equation (15)) and a negative term ($\pi/(r^k \beta)$ in equation (18));

(4) $C_i^k$ and $\epsilon_{ij}^\theta$ are family-specific and twin-specific realizations, respectively, of individual shock.

A few clarifying remarks might be useful. The variable $Z_{i,T}^k$ reflects the variance of the difference between a purely genetic component and its mean, conditional on the skill of the parents; so $\text{Var}(Z_{i1}^{k,MZ}) = \text{Var}(Z_{i1}^{k,DZ}) = \text{Cov}(Z_{i1}^{k,MZ}, Z_{i2}^{k,MZ}) = \sigma_k^2$, $\text{Cov}(Z_{i1}^{k,DZ}, Z_{i2}^{k,DZ}) = 0$, and not $\sigma_k^2/2$, as instead is $\text{Cov}(A_{i1}^{k,DZ}, A_{i2}^{k,DZ})$. The ambiguous effect of the family income on the skill is natural, because it is the sum of a direct effect (income of the family having a positive effect on, say, the intelligence of the child) and an indirect negative effect on the conditional probability of the genetic component of the parent (higher income of the family of the child is positively correlated with the income of the parent, which everything else being equal reduces the expected value of the genetic component, because the parent’s family income increased the parent’s intelligence). The $C_i^k$ and $\epsilon_{ij}^\theta$ components are the standard $C$ and $E$ components in the $ACE$ model.

**Linear Mixed Models**

We estimate the parameters of our model using a mixed linear model, as discussed by Rabe-Hesketh et al. (2008); see also McArdle and Prescott (2005). The mixed effects have three nested levels; the variables used in the estimate are defined as in Table 1. The highest level is defined by the family ID; the intermediate level is the twin type; the lowest level is the individual twin.

When the three variables are the only ones we consider, the mixed linear model estimates a standard $ACE$ decomposition. The variable twin type
Table 1. Illustration of the variables for the linear mixed models analysis

<table>
<thead>
<tr>
<th>Family ID</th>
<th>Member</th>
<th>MZ</th>
<th>Twin type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

Notes: Family ID identifies the family. Member is a variable identifying a twin within the family. Twin type is a variable that takes the same value (here 1) if the twins are MZ, and a different value if the twins are DZ.

allows us to use the difference in heritability between MZ and DZ twins. The crucial element is that the random effect corresponding to this level is constrained to be the same for MZ twins, and is independent for DZ twins. The variance for the random effect family ID corresponds to the variance of the shared environment ($\sigma^2(C)$) plus $1/2$ the variance of the genetic component (the $\sigma^2(A)$ variance of the $A$ variable in the $ACE$ model). The variance for the random effect twin type corresponds to the remaining $1/2$ of $\sigma^2(A)$. The third random effect corresponds to an individual specific error that is independent across twins, for both MZ and DZ twins.

An important advantage of the use of linear mixed models is that estimation can be easily extended from the classical $ACE$ or $ADE$ set-up to more general ones including fixed effects; we illustrate this use in the next section in a very simple case.

Illustration and Comparison with the ACE Model

To interpret the estimates of mobility and heritability, we present a simplified version of the complete model we estimate in later sections. Table 2 reports the results of three simple models; the skill we consider is intelligence measured by IQ. To interpret the results, it is important to keep in mind that all the variables (dependent and independent) are normalized to zero mean and unit standard deviation.

Model 1 presents the simple regression of the IQ of each twin on the IQ of the parents, defined as the average of the IQ of the two. The estimated coefficient is 0.479, so the fraction of variance of the IQ of the children explained by the parents’ average IQ is $0.479^2 = 0.23$.

Model 2 is the standard $ACE$ model, implemented as described in Section III, Linear Mixed Models. In the linear mixed model we only consider the random effects for the three levels in Table 1. The estimated variances are $\sigma^2_{\text{Fam}} = 0.523$ (SE = 0.042) for family ID, $\sigma^2_{\text{TT}} = 0.25$ (SE = 0.033) for twin type, and residual variance $\sigma^2_{\text{res}} = 0.21$ (SE = 0.011). Using the fact that $\sigma^2(A) = 2\sigma^2_{\text{TT}}$ and $\sigma^2(C) = \sigma^2_{\text{Fam}} - \sigma^2_{\text{TT}}$, we obtain the variance...
Table 2. Linear mixed models regression determination of IQ: a simple illustration

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>b/se</td>
<td>b/se</td>
<td>b/se</td>
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<tr>
<td><strong>Coefficients</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parents’ IQ</td>
<td>0.479***</td>
<td>0.484***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.018)</td>
<td>(0.023)</td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>0.046**</td>
<td>0.047**</td>
<td>0.045**</td>
</tr>
<tr>
<td></td>
<td>(0.018)</td>
<td>(0.026)</td>
<td>(0.023)</td>
</tr>
<tr>
<td><strong>Variances</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Var(A)</td>
<td>0.506***</td>
<td></td>
<td>0.279***</td>
</tr>
<tr>
<td></td>
<td>(0.066)</td>
<td></td>
<td>(0.035)</td>
</tr>
<tr>
<td>Var(C)</td>
<td>0.273***</td>
<td></td>
<td>0.263***</td>
</tr>
<tr>
<td></td>
<td>(0.067)</td>
<td></td>
<td>(0.033)</td>
</tr>
<tr>
<td>Var(E)</td>
<td>0.210***</td>
<td></td>
<td>0.209***</td>
</tr>
<tr>
<td></td>
<td>(0.01)</td>
<td></td>
<td>(0.010)</td>
</tr>
<tr>
<td>N</td>
<td>2,346</td>
<td>2,346</td>
<td>2,346</td>
</tr>
</tbody>
</table>

Notes: All independent variables are standardized to mean zero and standard deviation one. In this and all of
the following tables, *p < 0.1, **p < 0.05, and ***p < 0.01; standard errors are reported in parentheses.

for the A, C, and E variables reported in the table. By our normalization
of variables, the variances add approximately to one.

Model 3 combines the fixed and random effects, using the information
on the IQ score of the parents; so it is the estimation of the model presented
in equation (19). In Model 3, the normalization convention gives that the
sum of the square of the coefficient of the normalized parents’ IQ score and
the variances of the ACE variables adds to approximately 1. The variance
in equation (20) is estimated by the variance of the twin type variable.
The more precise estimate in Model 3 is consistent with the ACE estimate
of the variance of A in Model 2, as 0.279 + 0.484^2 = 0.513–0.506 (see
the second column of Table 2). Model 3 allows us to estimate the fraction
of the IQ of the children that can be estimated from the IQ of the parents
(0.484^2 = 0.234), which is in turn close to the 23 percent we had derived
from the simple regression of the children’s IQ on parents’ IQ in Model
1. Thus, the three models are consistent, and Model 3 gives the most
precise information. In Section VII, Determinants of Hard and Soft Skills,
Model 3 is estimated (with a richer set of variables) in Table 12 for IQ,
and in Tables A1–A3 in the Online Appendix for soft skills, to study how
traits are determined.

IV. Method

Sample

The sample was drawn from twin participants in the MTFS (Disney et al.,
1999; Iacono et al., 1999). The MTFS consists of two cohorts of twins,
A. Rustichini, W. G. Iacono, and M. McGue

one assessed initially at a target age of 11 (\(N = 1,512\)) and a second assessed initially at a target age of 17 (\(N = 1,252\)). Follow-up assessments were undertaken at the target ages of 20, 24, and 29 for the older cohort, and 14, 17, 20, 24, and 29 for the younger cohort. Rates of participation at MTFS follow-ups have generally been above 90 percent (McGue et al., 2014). In the present investigation, skill and family background data are drawn from the age-17 assessment, when participants were in their senior year of high school, and outcome data come from the age-24 and age-29 assessments. The sample used here is based on participants whose educational attainment could be determined at either the age-24 or age-29 assessment.

Of the total of 2,764 twins who completed an intake assessment, 2,598 (94.0 percent) qualified for the current study. Rate of inclusion was modestly but significantly associated with participant sex (males = 92.7 percent, females = 95.2 percent, \(\chi^2\) (one degree of freedom (1 dof)) = 4.40, \(p = 0.04\)), cohort (11-year-olds = 92.0 percent, 17-year-olds = 96.4 percent, \(\chi^2\) (1 dof) = 13.2, \(p < 0.001\)), and intake cognitive ability (standardized mean difference, \(d = 0.29\), \(\chi^2\) (1 dof) = 7.22, \(p = 0.007\)), but not associated with family background or non-cognitive skills. Additional details of the ascertainment of the MTFS sample can be found in Iacono et al. (1999).

Measures

Cognitive Ability. Cognitive ability was assessed at intake for both MTFS cohorts using four subtests from the age-appropriate Wechsler Intelligence Scale. Twins in the younger cohort were assessed with the Wechsler Intelligence Scale for Children – Revised (WISC-R) and twins in the older cohort were assessed with the Wechsler Adult Intelligence Scale – Revised (WAIS-R). The short forms consisted of two performance subtests (block design and picture arrangement) and two verbal subtests (information and vocabulary), and the scaled scores from these subtests were prorated to determine overall IQ. The IQ from this short form has been shown to correlate \((r = 0.94)\) with the IQ from the complete test (Sattler, 1974).

Non-Cognitive Skills: MPQ Personality Measures. Six measures of non-cognitive skills derived from the age-17 assessment of both cohorts were used. First, we used three higher-order scales from the Multidimensional Personality Questionnaire (MPQ; Tellegen and Waller, 2008). The MPQ has 11 primary trait scales (absorption, well-being, social potency, achievement, social closeness, stress reaction, aggression, alienation, control, harm avoidance, traditionalism). Each is assessed with 18 self-reported items. The three higher-order MPQ scales – positive emotionality (here PE),
negative emotionality (NE), and constraint (CN) – are computed as linear functions of the 11 primary scales. High CN is associated with tendencies to inhibit and constrain impulsive, as well as risk-taking, behavior. Individuals with higher NE scores are more prone to experience anxiety, anger, and in general negative engagement. PE is associated with the search for rewarding behavior and experience, while low PE can be associated with loss of interest, depressive engagement, and fatigue.

In our sample, the three higher-order dimensions, as well as IQ, are approximately normally distributed.

Additional Non-Cognitive Skills. Three additional measures of soft skills were derived from answers to questionnaires, as follows.

The externalizing scale was the total number of symptoms of oppositional defiant disorder, conduct disorder, and adult antisocial behavior (i.e., the adult symptoms used in diagnosing antisocial personality disorder) classified in the Fourth Edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV), obtained by interviewing the twin using the Diagnostic Interview for Children and Adolescents (DICA-R; Welner et al., 1987; Reich, 2000), and the Structured Clinical Interview for DSM-III-R (SCID; Spitzer et al., 1992). The interviews were modified to ensure complete coverage of DSM-IV symptoms reported over the lifetime of the adolescent. In the analysis reported here, the externalizing scale was log-transformed (after adding 1) to minimize positive skew.

The academic effort scale consisted of eight items answered by the twins’ mother on a four-point scale (definitely false, probably false, probably true, definitely true). Items on this scale ($\alpha = 0.91$; Cronbach, 1951) cover academic effort (e.g., “Turns in homework on time”) and motivation (“Wants to earn good grades”).

Finally, the academic problems scale consisted of three items ($\alpha = 0.77$) answered in the same four-response format by the mother and covering behavioral problems in a school setting (e.g., “Easily distracted in class”).

Family Background. Three indicators of family background assessed at intake were analyzed here. First, parent occupational status was based on mothers’ and fathers’ reports and coded using the Hollingshead scale (Hollingshead, 1957). We inverted the 1–7 point Hollingshead scale, so that higher scores represented higher occupational status. Individuals were coded as missing if they did not work full-time, were disabled or institutionalized, or reported their occupation as homemaker. The occupation status of the home was taken as the maximum of the two parent reports. Parent college was the number of parents having completed a four-year college degree. Finally, family income was measured on a 13-point, self-reported scale that ranged from 1 = less than $10,000 to 13 = over $80,000.
**Outcome Measures.** Five dichotomous outcome measures were obtained through self-reporting at the age-29 assessment. The first five are 0/1 variables.

College = 1 if the person completed a four-year undergraduate degree (by the time of the age-29 assessment). Currently married = 1 if the person was legally married at the age-29 assessment, engaged full-time = 1 if either going to school full-time, having a full-time job, or being a parent full-time, financial independence = 1 if not living with parents, receiving financial support from parents, or on government assistance, and legal problems = 1 if either sent to jail, arrested, gone to court, or had troubles with drugs and alcohol.

A final outcome measure, grade point average (GPA) at 17, was based on a mother’s report of how well her child was doing in school at the age-17 assessment (i.e., the final year of high school). These reports were on a five-point scale (4 = mostly A grades, 3 = mostly B, 2 = mostly C, 1 = mostly D, 0 = mostly F). In an earlier report, we found that mother’s grade reports correlated 0.89 with the GPA determined from school transcripts (Johnson *et al.*, 2006, 2007).

**Composite Measures.** In order to investigate the joint effect of predictors in the three separate domains, two composites were formed (as the cognitive domain only included the single measure of IQ, no composite was needed there).

A non-cognitive composite was computed by summing the standardized scores on the six individual non-cognitive measures (NE, externalizing, and academic problems were reflected). A family background composite was formed by summing the standardized scores for the three family background measures. The internal consistency reliability was estimated as 0.67 and 0.70, respectively, for the two composites, which were standardized in the analysis reported here.

**Descriptive Statistics**

Table 3(a) reports the descriptive statistics for the main predictor variables. The table shows small and significant differences across genders in some of the traits (intelligence and CN). The distribution of IQ, PE, NE, and CN is approximately normal. In Table 3(b), larger and significant outcomes among genders are clear for college (larger by 13 percent for women) and legal problems (larger by 9 percent for men).

Table 4 reports the correlation among the skill variables used. Correlations between IQ scores and MPQ scales are low (they are all below 10 percent) and in the ranges usually found in similar studies. The correlation between CN and IQ is negative, and a comment on this might be
### Table 3(a). Descriptive statistics for predictor variables

<table>
<thead>
<tr>
<th>Measures</th>
<th>Males</th>
<th>Females</th>
<th>Standardized difference (95 percent CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cognitive</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IQ</td>
<td>104.1</td>
<td>100.5</td>
<td>0.29</td>
</tr>
<tr>
<td>(13.8)</td>
<td></td>
<td>(14.2)</td>
<td>(0.21,0.36)</td>
</tr>
<tr>
<td><strong>Non-cognitive</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive emotionality</td>
<td>124.0</td>
<td>123.0</td>
<td>0.07</td>
</tr>
<tr>
<td>(12.5)</td>
<td></td>
<td>(14.5)</td>
<td>(−0.01,0.15)</td>
</tr>
<tr>
<td>Negative emotionality</td>
<td>90.6</td>
<td>88.4</td>
<td>0.15</td>
</tr>
<tr>
<td>(13.6)</td>
<td></td>
<td>(14.5)</td>
<td>(−0.01, 0.16)</td>
</tr>
<tr>
<td>Constraint</td>
<td>130.1</td>
<td>138.2</td>
<td>−0.52</td>
</tr>
<tr>
<td>(15.1)</td>
<td></td>
<td>(15.6)</td>
<td>(−0.61,−0.44)</td>
</tr>
<tr>
<td>Externalizing</td>
<td>−0.03</td>
<td>−0.18</td>
<td>0.41</td>
</tr>
<tr>
<td>(−0.37)</td>
<td>(−0.29)</td>
<td>(0.31, 0.52)</td>
<td></td>
</tr>
<tr>
<td>Academic effort</td>
<td>25.6</td>
<td>28.2</td>
<td>−0.45</td>
</tr>
<tr>
<td>(−5.2)</td>
<td>(−5.7)</td>
<td>(−0.56,−0.35)</td>
<td></td>
</tr>
<tr>
<td>Academic problems</td>
<td>5.6</td>
<td>5.1</td>
<td>0.22</td>
</tr>
<tr>
<td>(−2.1)</td>
<td>(−2)</td>
<td>(0.11,0.33)</td>
<td></td>
</tr>
<tr>
<td>Non-cognitive composite</td>
<td>−0.21</td>
<td>0.19</td>
<td>−0.4</td>
</tr>
<tr>
<td>(−1)</td>
<td>(−0.97)</td>
<td>(−0.50,−0.30)</td>
<td></td>
</tr>
<tr>
<td><strong>Family background</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Income</td>
<td>8.6</td>
<td>9</td>
<td>−0.12</td>
</tr>
<tr>
<td>(−3.2)</td>
<td>(−3)</td>
<td>(−0.23,−0.01)</td>
<td></td>
</tr>
<tr>
<td>Parental occupational status</td>
<td>4.3</td>
<td>4.4</td>
<td>−0.03</td>
</tr>
<tr>
<td>(−1.5)</td>
<td>(−1.6)</td>
<td>(−0.14,0.08)</td>
<td></td>
</tr>
<tr>
<td>Parent college</td>
<td>0.54</td>
<td>0.54</td>
<td>0</td>
</tr>
<tr>
<td>(−0.77)</td>
<td>(−0.76)</td>
<td>(−0.11,0.11)</td>
<td></td>
</tr>
<tr>
<td>Background composite</td>
<td>−0.03</td>
<td>0.04</td>
<td>−0.07</td>
</tr>
<tr>
<td>(−1.01)</td>
<td>(−0.99)</td>
<td>(−0.17,0.04)</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:** Standardized mean difference computed as male mean minus female mean, divided by pooled standard deviation.

### Table 3(b). Descriptive statistics for outcome variables

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>Males</th>
<th>Females</th>
<th>Odds ratios (95 percent CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offspring college</td>
<td>38.90%</td>
<td>52.30%</td>
<td>1.73</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(1.43,2.10)</td>
</tr>
<tr>
<td>Currently married</td>
<td>48.30%</td>
<td>53.80%</td>
<td>1.25</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(1.04,1.49)</td>
</tr>
<tr>
<td>Engaged full-time</td>
<td>90.50%</td>
<td>89.70%</td>
<td>0.91</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.69,1.21)</td>
</tr>
<tr>
<td>Financial independence</td>
<td>78.30%</td>
<td>78.60%</td>
<td>1.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.82,1.25)</td>
</tr>
<tr>
<td>Legal problems</td>
<td>21.20%</td>
<td>12.30%</td>
<td>0.52</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.42,0.66)</td>
</tr>
</tbody>
</table>

**Notes:** Odds ratio (OR) is scaled such that OR > 1 reflects a higher percentage in women.

Table 4. Correlation among cognitive and non-cognitive skills

<table>
<thead>
<tr>
<th></th>
<th>IQ</th>
<th>PE</th>
<th>NE</th>
<th>CN</th>
<th>Ext.</th>
<th>Ac. eff.</th>
</tr>
</thead>
<tbody>
<tr>
<td>PE</td>
<td>0.0956</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NE</td>
<td>−0.0837</td>
<td>−0.1031</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CN</td>
<td>−0.0941</td>
<td>0.1446</td>
<td>−0.0948</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Externalizing</td>
<td>−0.0881</td>
<td>−0.0242</td>
<td>0.1974</td>
<td>−0.4535</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Academic effort</td>
<td>0.1762</td>
<td>0.1947</td>
<td>−0.1542</td>
<td>0.3726</td>
<td>−0.5064</td>
<td></td>
</tr>
<tr>
<td>Academic problems</td>
<td>−0.2207</td>
<td>−0.0462</td>
<td>0.1535</td>
<td>−0.2998</td>
<td>0.3889</td>
<td>−0.6132</td>
</tr>
</tbody>
</table>

Notes: IQ denotes IQ score; PE, positive emotionality; NE, negative emotionality; CN, constraint. All correlations are significant at \( p < 0.0001 \), so the significance level is not reported.

useful. CN is a composite scale of three MPQ primary scales. Two of these are negatively correlated with IQ: traditionalism \( (r = −0.086) \) and harm avoidance \( (r = −0.204) \). The third, control, has a positive correlation with IQ \( (r = −0.056, p = 0.006; \) all the other correlations in this section are at \( p < 0.001 \)). Hence, there is overall negative correlation of CN with IQ. The correlation between MPQ scales is also low (between 10 and 15 percent). Academic effort, a variable closer to the performance in education, is naturally highly correlated with CN \( (r = 0.39) \) and in smaller measure with PE, NE, and IQ.

V. Educational Achievement

The older twins in our sample are currently aged around 29–30; thus, the data on income are still fragmentary and not fully indicative of the lifetime income of the individual. So, in the estimation of the equations of the model, we focus on the educational achievement and on the skill formation.

College

The estimation of factors affecting college attainment is reported in Table 5. Entries in the table report the odd ratios, or more precisely the factor that multiplies the odd ratio as the relevant variable changes by one standard deviation, which in our case, where all variables are standardized, is the same as changing from 0 to 1.

The univariate estimate for each of the variables in Table 5 (see Table A4 in the Online Appendix) shows that all variables have a sizeable and significant effect on college attainment. Hard skills, soft skills, and family background are all related in the expected way to college. Table 5, which reports the results of regression analysis conditioning on different sets of variables, shows a clearer picture.
Table 5. College attainment (= 1 if the individual has a college degree), personality, and family background: logistic regression (odds ratios reported)

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
<th>Model 5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>b/se</td>
<td>b/se</td>
<td>b/se</td>
<td>b/se</td>
<td>b/se</td>
</tr>
<tr>
<td>Male</td>
<td>0.666***</td>
<td>0.838***</td>
<td>0.745***</td>
<td>0.862**</td>
<td>0.876*</td>
</tr>
<tr>
<td></td>
<td>(0.035)</td>
<td>(0.046)</td>
<td>(0.043)</td>
<td>(0.059)</td>
<td>(0.062)</td>
</tr>
<tr>
<td>IQ</td>
<td>2.091***</td>
<td>2.096***</td>
<td>1.823***</td>
<td>1.646***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.111)</td>
<td>(0.119)</td>
<td>(0.121)</td>
<td>(0.114)</td>
<td></td>
</tr>
<tr>
<td>PE</td>
<td>1.328***</td>
<td>1.271***</td>
<td>1.211***</td>
<td>1.204***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.065)</td>
<td>(0.066)</td>
<td>(0.077)</td>
<td>(0.075)</td>
<td></td>
</tr>
<tr>
<td>NE †</td>
<td>1.298***</td>
<td>1.246***</td>
<td>1.167**</td>
<td>1.142**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.061)</td>
<td>(0.062)</td>
<td>(0.071)</td>
<td>(0.073)</td>
<td></td>
</tr>
<tr>
<td>CN</td>
<td>1.302***</td>
<td>1.418***</td>
<td>1.065</td>
<td>1.145*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.067)</td>
<td>(0.078)</td>
<td>(0.076)</td>
<td>(0.085)</td>
<td></td>
</tr>
<tr>
<td>Externalizing at 17 †</td>
<td></td>
<td></td>
<td>1.217**</td>
<td>1.187*</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.106)</td>
<td>(0.110)</td>
<td></td>
</tr>
<tr>
<td>Academic effort at 17</td>
<td></td>
<td></td>
<td>2.012***</td>
<td>1.908***</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.198)</td>
<td>(0.192)</td>
<td></td>
</tr>
<tr>
<td>Academic problems at 17 †</td>
<td></td>
<td></td>
<td>1.163*</td>
<td>1.175*</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.096)</td>
<td>(0.099)</td>
<td></td>
</tr>
<tr>
<td>College of parents</td>
<td></td>
<td></td>
<td>1.458***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.104)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Household income</td>
<td></td>
<td></td>
<td>1.323***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.096)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parents’ occ. status</td>
<td></td>
<td></td>
<td>1.061</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.077)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>0.826***</td>
<td>0.916*</td>
<td>0.883**</td>
<td>0.888*</td>
<td>0.868***</td>
</tr>
<tr>
<td></td>
<td>(0.043)</td>
<td>(0.048)</td>
<td>(0.048)</td>
<td>(0.060)</td>
<td>(0.061)</td>
</tr>
<tr>
<td>N</td>
<td>2,593</td>
<td>2,345</td>
<td>2,341</td>
<td>1,857</td>
<td>1,840</td>
</tr>
</tbody>
</table>

Notes: Standard error of odds ratio in parentheses. The variable college of parents is = 1 if at least one of the parents has a college degree, = 0 otherwise. All independent variables, including college of parents, are standardized to mean zero and one standard deviation. The † indicates that NE, externalizing at 17, and academic problems at 17 are taken with a negative sign to make comparison easier.

In all models, the male variable is associated with a significant reduction of the probability of college attainment, in the range between 3 and 8 percent. Although it is natural to conjecture that this gender effect is the result of a subtle interplay between gender and personality, the estimation of the interaction between gender and the traits, including IQ, is not significant. Models 1–3 show that all the personality variables (both hard and soft) have the expected sign, and significant and large effects. A difference of one standard deviation above the mean in IQ is associated with an increase in probability of having a college degree from the baseline of 45.9 percent to 60 percent. The interaction with gender is positive for female, but small (2 percent) and not significant (p = 0.18).

In the joint model (Model 3), intelligence has a larger effect size than each of the other three MPQ higher-order dimensions; the estimated odds ratio is around 2 for intelligence, and between 1.25 and 1.4 for the...
three higher-order personality traits; so the joint effect of these three is comparable with that of intelligence. In the logistic regression (not reported in the tables) of IQ and the composite measure of the three MPQ higher dimension variables, the coefficient of IQ is 2.1, and that of the composite 1.29.

Model 4 illustrates the role of the intermediate soft skills. All three have significant and large effects. The estimated odds ratios for PE and NE change little after we introduce these intermediate variables, while that of CN is reduced. This finding is consistent with the natural interpretation that the three variables (externalizing, academic effort, and academic problems, which are closer to the outcomes than the IQ score and the MPQ higher dimensions scales) are representing, in different and independent ways, the role of CN in educational achievement. This is also consistent with the correlation between CN and these three variables reported in Table 4, where the absolute value of $r$ ranges between 0.30 (for academic problems) and 0.45 (for externalizing). The estimated odds ratio for intelligence is also reduced. None of the three variables seems to be associated in particular with this reduction in the odds ratio for CN.

Finally, Model 5 illustrates the effect of family background. Both college of parents and family income have significant and independent positive effects. The variable, college of parents, is equal to 1 when at least one of the parents has a college degree. Entering the college of the father and the mother separately shows no significant difference in the estimated coefficient for the two. Replacing college of parents with education of parents produces the same result: the estimated odds ratios for education of parents is 1.53, with $SE = 0.11$ and $z = 5.94$.

In the logistic model presented in Table 5, we controlled for the correlation between the two twins with a Hubert–White sandwich estimator. Two tables in the Online Appendix check for robustness of the results to a GLS regression (see Table A6) and to a fixed effects specification (see Table A7). We also check the robustness of the results with the linear mixed effects model discussed in Section III, Linear Mixed Models; the results are presented in Table 6. The reported coefficients indicate the change in probability associated with a one unit change in standard deviation of the variable.

The estimates are consistent with the results of the logistic model, namely an increase by approximately 15 percent for intelligence, and a change of approximately 5 percent induced by the higher-order MPQ traits.

In the complete model, (Model 5), intelligence has the largest effect among hard and soft skills (9 percent as opposed to 3 percent of PE and NE). In this model too, the predictive power of CN is probably taken by the intermediate soft skills measures; in particular academic effort, which contributes about 10 percent. The education of the parents and
### Table 6. College attainment: mixed effects linear regression

<table>
<thead>
<tr>
<th></th>
<th>Model 1 b/se</th>
<th>Model 2 b/se</th>
<th>Model 3 b/se</th>
<th>Model 4 b/se</th>
<th>Model 5 b/se</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>−0.088***</td>
<td>−0.044***</td>
<td>−0.064***</td>
<td>−0.032**</td>
<td>−0.027**</td>
</tr>
<tr>
<td></td>
<td>(0.011)</td>
<td>(0.012)</td>
<td>(0.012)</td>
<td>(0.013)</td>
<td>(0.012)</td>
</tr>
<tr>
<td>IQ</td>
<td>0.144***</td>
<td>0.142***</td>
<td>0.113***</td>
<td>0.092***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.010)</td>
<td>(0.010)</td>
<td>(0.012)</td>
<td>(0.012)</td>
<td></td>
</tr>
<tr>
<td>PE</td>
<td>0.055***</td>
<td>0.045***</td>
<td>0.036***</td>
<td>0.033***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.010)</td>
<td>(0.010)</td>
<td>(0.010)</td>
<td>(0.010)</td>
<td></td>
</tr>
<tr>
<td>NE †</td>
<td>0.053***</td>
<td>0.042***</td>
<td>0.029***</td>
<td>0.025**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.010)</td>
<td>(0.009)</td>
<td>(0.010)</td>
<td>(0.010)</td>
<td></td>
</tr>
<tr>
<td>CN</td>
<td>0.055***</td>
<td>0.064***</td>
<td>0.014</td>
<td>0.023*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.010)</td>
<td>(0.010)</td>
<td>(0.012)</td>
<td>(0.012)</td>
<td></td>
</tr>
<tr>
<td>Externalizing at 17 †</td>
<td></td>
<td>0.040***</td>
<td>0.034**</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.015)</td>
<td>(0.014)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Academic effort at 17</td>
<td></td>
<td>0.114***</td>
<td>0.105***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.015)</td>
<td>(0.015)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Academic problems at 17 †</td>
<td></td>
<td>0.035**</td>
<td>0.034**</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.014)</td>
<td>(0.014)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>College of parents</td>
<td></td>
<td></td>
<td></td>
<td>0.076***</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.013)</td>
<td></td>
</tr>
<tr>
<td>Household income</td>
<td></td>
<td></td>
<td></td>
<td>0.048***</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.013)</td>
<td></td>
</tr>
<tr>
<td>Parents’ occ. status</td>
<td></td>
<td></td>
<td></td>
<td>0.011</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.013)</td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>0.454***</td>
<td>0.473***</td>
<td>0.467***</td>
<td>0.485***</td>
<td>0.479***</td>
</tr>
<tr>
<td></td>
<td>(0.011)</td>
<td>(0.012)</td>
<td>(0.011)</td>
<td>(0.012)</td>
<td>(0.012)</td>
</tr>
<tr>
<td>N</td>
<td>2,593</td>
<td>2,345</td>
<td>2,341</td>
<td>1,857</td>
<td>1,840</td>
</tr>
</tbody>
</table>

**Notes:** College of parents is = 1 if at least one of the parents has a college degree, and = 0 otherwise. All independent variables, including college of parents, are standardized to mean zero and one standard deviation. The † indicates that NE, externalizing at 17, and academic problems at 17 are taken with a negative sign to make comparison easier.

Family income are both significant and substantial (8 percent for college of parents, and 5 percent for income). The fraction of variance explained by the independent variables is approximately 25 percent. The pseudo $R^2$ of the complete Model 5 of Table 5 is 0.231; the $R^2$ of the linear model is 0.27.

### GPA Scores

Hard and soft skills and family background affect an educational outcome measured at a much earlier age (GPA at 17), and are consistent in direction with what we have seen for college attainment. There are significant differences in the effect size of the independent variables. The estimated coefficients in the univariate linear regressions are in Table A5 in the Online Appendix. The results of the mixed effects regression are reported in Table 7, where both dependent and independent variables are standardized,
Table 7. High-school GPA as reported by mother: mixed effects linear regression

<table>
<thead>
<tr>
<th></th>
<th>Model 1 b/se</th>
<th>Model 2 b/se</th>
<th>Model 3 b/se</th>
<th>Model 4 b/se</th>
<th>Model 5 b/se</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>−0.304***</td>
<td>−0.191***</td>
<td>−0.239***</td>
<td>−0.131***</td>
<td>−0.123***</td>
</tr>
<tr>
<td></td>
<td>(0.024)</td>
<td>(0.026)</td>
<td>(0.024)</td>
<td>(0.020)</td>
<td>(0.020)</td>
</tr>
<tr>
<td>IQ</td>
<td>0.342***</td>
<td>0.338***</td>
<td>0.224***</td>
<td>0.204***</td>
<td>0.204***</td>
</tr>
<tr>
<td></td>
<td>(0.020)</td>
<td>(0.020)</td>
<td>(0.017)</td>
<td>(0.018)</td>
<td>(0.018)</td>
</tr>
<tr>
<td>PE</td>
<td>0.071***</td>
<td>0.055***</td>
<td>0.008</td>
<td>0.006</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.018)</td>
<td>(0.017)</td>
<td>(0.015)</td>
<td>(0.015)</td>
<td></td>
</tr>
<tr>
<td>NE †</td>
<td>0.099***</td>
<td>0.079***</td>
<td>0.027*</td>
<td>0.025*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.018)</td>
<td>(0.017)</td>
<td>(0.015)</td>
<td>(0.015)</td>
<td></td>
</tr>
<tr>
<td>CN</td>
<td>0.169***</td>
<td>0.190***</td>
<td>0.026</td>
<td>0.032*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.019)</td>
<td>(0.018)</td>
<td>(0.017)</td>
<td>(0.017)</td>
<td></td>
</tr>
<tr>
<td>Externalizing at 17 †</td>
<td>0.027</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.022)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Academic effort at 17</td>
<td>0.502***</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.023)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Academic problems at 17 †</td>
<td>0.120***</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.021)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>College of parents</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.044***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.022)</td>
</tr>
<tr>
<td>Household income</td>
<td></td>
<td></td>
<td></td>
<td>0.038*</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.021)</td>
<td></td>
</tr>
<tr>
<td>Parents’ occ. status</td>
<td></td>
<td></td>
<td></td>
<td>0.041*</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.021)</td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>−0.009</td>
<td>0.019</td>
<td>0.003</td>
<td>−0.004</td>
<td>−0.007</td>
</tr>
<tr>
<td></td>
<td>(0.023)</td>
<td>(0.026)</td>
<td>(0.023)</td>
<td>(0.019)</td>
<td>(0.019)</td>
</tr>
<tr>
<td>N</td>
<td>2,261</td>
<td>2,076</td>
<td>2,074</td>
<td>1,852</td>
<td>1,837</td>
</tr>
</tbody>
</table>

Notes: College of parents is = 1 if at least one of the parents has a college degree, and = 0 otherwise. All independent variables, including college of parents and the GPA score, are standardized to mean zero and one standard deviation. The † indicates that NE, externalizing at 17, and academic problems at 17 are taken with a negative sign to make comparison easier.

so the coefficients indicate the change (in standard deviation units) of a corresponding change in the independent variable.

The male variable is associated with a 13.5 percent decrease. The hard skill intelligence has a much larger effect on grades than on college attainment, when compared to the higher-order MPQ dimensions – by a factor of around 10 in the complete model (Model 5). The intermediate soft skills (which are very close to the specific outcome we are considering here, in particular academic effort) have a large effect, and it is likely that they take a great part of the predictive power of the MPQ traits. It is interesting to note that, of the MPQ variables, in Model 3, CN has the largest size coefficient, 19 percent (which is large, even compared to intelligence, 34 percent). The background of an educated family has a positive effect on grades (e.g., college of parents is associated with a 5 percent increase); household income has instead no significant effect.
Skills and family background

Table 8. Social and economic outcomes, personality, and family background: logistic regression (odds ratios reported)

<table>
<thead>
<tr>
<th></th>
<th>Final independence b/se</th>
<th>Full-time engaged b/se</th>
<th>Currently married b/se</th>
<th>Legal problems b/se</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>1.109</td>
<td>1.375***</td>
<td>1.045</td>
<td>1.115</td>
</tr>
<tr>
<td></td>
<td>(0.086)</td>
<td>(0.139)</td>
<td>(0.059)</td>
<td>(0.089)</td>
</tr>
<tr>
<td>IQ</td>
<td>1.198**</td>
<td>0.958</td>
<td>0.874**</td>
<td>0.881</td>
</tr>
<tr>
<td></td>
<td>(0.104)</td>
<td>(0.101)</td>
<td>(0.050)</td>
<td>(0.073)</td>
</tr>
<tr>
<td>PE</td>
<td>1.171**</td>
<td>1.141</td>
<td>1.159***</td>
<td>1.247***</td>
</tr>
<tr>
<td></td>
<td>(0.091)</td>
<td>(0.115)</td>
<td>(0.064)</td>
<td>(0.101)</td>
</tr>
<tr>
<td>NE †</td>
<td>1.099</td>
<td>1.022</td>
<td>0.975</td>
<td>0.920</td>
</tr>
<tr>
<td></td>
<td>(0.082)</td>
<td>(0.096)</td>
<td>(0.049)</td>
<td>(0.067)</td>
</tr>
<tr>
<td>CN</td>
<td>1.026</td>
<td>1.129</td>
<td>1.117*</td>
<td>0.762***</td>
</tr>
<tr>
<td></td>
<td>(0.093)</td>
<td>(0.128)</td>
<td>(0.071)</td>
<td>(0.065)</td>
</tr>
<tr>
<td>Ext. at 17 †</td>
<td>1.033</td>
<td>1.123</td>
<td>1.136*</td>
<td>0.696***</td>
</tr>
<tr>
<td></td>
<td>(0.103)</td>
<td>(0.125)</td>
<td>(0.077)</td>
<td>(0.056)</td>
</tr>
<tr>
<td>Ac. effort at 17</td>
<td>1.198*</td>
<td>1.455***</td>
<td>1.133</td>
<td>0.932</td>
</tr>
<tr>
<td></td>
<td>(0.118)</td>
<td>(0.158)</td>
<td>(0.087)</td>
<td>(0.093)</td>
</tr>
<tr>
<td>Ac. problems at 17 †</td>
<td>0.899</td>
<td>0.856</td>
<td>0.983</td>
<td>0.991</td>
</tr>
<tr>
<td></td>
<td>(0.083)</td>
<td>(0.101)</td>
<td>(0.064)</td>
<td>(0.092)</td>
</tr>
<tr>
<td>College</td>
<td>1.188**</td>
<td>1.206*</td>
<td>1.109*</td>
<td>0.821***</td>
</tr>
<tr>
<td></td>
<td>(0.103)</td>
<td>(0.131)</td>
<td>(0.064)</td>
<td>(0.068)</td>
</tr>
<tr>
<td>College of parents</td>
<td>0.976</td>
<td>0.869</td>
<td>1.014</td>
<td>0.737***</td>
</tr>
<tr>
<td></td>
<td>(0.087)</td>
<td>(0.096)</td>
<td>(0.061)</td>
<td>(0.064)</td>
</tr>
<tr>
<td>Household income</td>
<td>0.925</td>
<td>1.068</td>
<td>0.918</td>
<td>1.040</td>
</tr>
<tr>
<td></td>
<td>(0.077)</td>
<td>(0.115)</td>
<td>(0.055)</td>
<td>(0.086)</td>
</tr>
<tr>
<td>Parents’ occ. status</td>
<td>1.138*</td>
<td>1.005</td>
<td>0.927</td>
<td>1.101</td>
</tr>
<tr>
<td></td>
<td>(0.085)</td>
<td>(0.096)</td>
<td>(0.053)</td>
<td>(0.090)</td>
</tr>
<tr>
<td>Constant</td>
<td>6.509***</td>
<td>11.988***</td>
<td>1.174***</td>
<td>0.143***</td>
</tr>
<tr>
<td></td>
<td>(0.490)</td>
<td>(1.168)</td>
<td>(0.062)</td>
<td>(0.011)</td>
</tr>
<tr>
<td>N</td>
<td>1,778</td>
<td>1,778</td>
<td>1,840</td>
<td>1,780</td>
</tr>
</tbody>
</table>

Notes: The four outcomes are financial independence, full-time engaged, currently married, and legal problems. Standard error of odds ratio in parentheses. College and college of parents are = 1 if at least one of the parents has a college degree, and = 0 otherwise. All independent variables, including college of parents, are standardized to mean zero and one standard deviation. The † indicates that NE, externalizing at 17, and academic problems at 17 are taken with a negative sign to make comparison easier.

In summary, for high-school grades, intelligence has a substantially larger effect than personality measures; and family background has a small effect (i.e., small for parents’ education and negligible for income).

For high-school GPA, the fraction of variance explained by the predictors is larger than for college: the overall $R^2$ in the panel regression is 0.53.

VI. Social and Economic Outcomes

Other important social and economic outcomes are related in ways similar to the way college attainment is by hard and soft skills.

Table 8 reports the logit regressions (in parallel with the analysis of Model 5 in Table 5 for college attainment).
Table 9. Frequency of parents having a college degree, by gender of the parents

<table>
<thead>
<tr>
<th></th>
<th>Mother, no college</th>
<th>Mother, college</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Father, no college</td>
<td>1,676</td>
<td>244</td>
<td>1,920</td>
</tr>
<tr>
<td></td>
<td>61.8</td>
<td>9</td>
<td>70.9</td>
</tr>
<tr>
<td>Father, college</td>
<td>340</td>
<td>448</td>
<td>788</td>
</tr>
<tr>
<td></td>
<td>12.56</td>
<td>16.54</td>
<td>29.1</td>
</tr>
<tr>
<td>Total</td>
<td>2,016</td>
<td>692</td>
<td>2,708</td>
</tr>
<tr>
<td></td>
<td>74.45</td>
<td>25.55</td>
<td></td>
</tr>
</tbody>
</table>

Notes: Numbers in italics are the fraction of the total.

Tables A8–A11 in the Online Appendix report a detailed analysis comparing different models.

Hard-skill intelligence has a substantial ($OR = 1.25$) and significant effect on financial independence, as expected, even after we control for college (which has a significant and large effect $OR = 1.2$). It has a surprising and negative ($OR = 0.86$) effect on the outcome measure, currently married. We must consider that subjects in the sample are still relatively young at the time of the assessment (29 years, on average) so this might be more informative about the timing of marriage rather than the lifetime trend.

The higher-order MPQ dimension CN has a strong effect, in particular, on reducing the probability of legal problems ($OR = 0.73$). The probability of having legal problems is also reduced substantially by parents having a college degree ($OR = 0.75$), as well as the subject having a college degree ($OR = 0.82$). The result is noticeable as we are controlling for other possibly related variables (such as intelligence of the individual and family income), which instead have no direct effect. More proximate variables, such as externalizing behavior, have the natural effect, which is also strong ($OR = 1.48$).

Overall, considering the pattern common to all these social outcomes, we can conclude that hard and soft skills have separate, independent, and strong effects on social outcomes.

VII. Educational Mobility

The fraction of individuals with a college degree in the population we are considering has increased over time, and the proportion of males and females also has shifted. If we first consider parents, we find that 37.6 percent of the population of parents have a college degree. For this generation, males were more likely to go to college and complete a college degree: 29.1 percent of fathers in our sample have a college degree, and 25.4 percent of mothers. Table 9 reports the frequency of parents having a college degree for pairs of parents.
Table 10. Frequency of offspring having a college degree

<table>
<thead>
<tr>
<th></th>
<th>No college</th>
<th>College</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Both parents, no college</td>
<td>1,076</td>
<td>535</td>
<td>1,722</td>
</tr>
<tr>
<td></td>
<td>66.8</td>
<td>33.2</td>
<td>100</td>
</tr>
<tr>
<td>At least one parent, college</td>
<td>324</td>
<td>659</td>
<td>1,038</td>
</tr>
<tr>
<td></td>
<td>32.9</td>
<td>67.1</td>
<td>100</td>
</tr>
<tr>
<td>Total</td>
<td>1,591</td>
<td>1,169</td>
<td></td>
</tr>
<tr>
<td></td>
<td>53.9</td>
<td>46.1</td>
<td></td>
</tr>
</tbody>
</table>

Notes: The frequency of offspring having a college degree depends on at least one of the parents having a college degree. Numbers in italics are the fraction of the row total.

To take into account the link between parents and children having a college degree, we define a variable, college of parents, equal to 1 when at least one of the parents has a college degree (38.1 percent of the cases), and compute the transition probability from college of the parents to college of children. Table 10 reports the frequencies.

The long-run frequency (described by the invariant distribution) of college for children is approximately 50 percent, higher than the observed 46.1 percent, as expected in a period in which going to college after school was becoming more frequent. There is a substantial difference across genders in the fraction going to college: for males, the fraction is 39 percent, for females, it is 52.3 percent. In the same direction, for the two corresponding subgroups of individuals whose parents did or did not have a college degree, the difference is 27.4 percent of males with parents with no college degree have a college degree, as opposed to 38.5 percent; for the group with parents with a college degree, the difference is even larger (i.e., 58 percent for males, 74.6 percent for females; see Tables A12 and A13 in the Online Appendix).

Determinants of Educational Mobility

To obtain a first evaluation of the comparative effect of hard and soft skills on mobility, we can define a mobility variable: equal to 1 if the college attainment of the children is higher than those of parents (i.e., if the child has a college degree and neither of the parents have a college degree); equal to 0 if it is equal to that of the parents (i.e., if neither child nor parents have a degree, or the child and at least one of the parents have); equal to −1 if the child does not have a degree and at least one of the parents has. The independent variables are the difference between a child’s skill (intelligence or MPQ personality) and the average of the parents’ score, standardized. The results are in Table 11.

Entries describe the change in the odds of being in a mobility category or larger over being in any of the lower categories, following a unit change.
Table 11. Ordered logit of intergenerational mobility

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
<th>Model 5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>b/se</td>
<td>b/se</td>
<td>b/se</td>
<td>b/se</td>
<td>b/se</td>
</tr>
<tr>
<td>Difference IQ</td>
<td>1.484***</td>
<td>1.478***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.076)</td>
<td>(0.085)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difference PE</td>
<td>1.159***</td>
<td></td>
<td>1.257***</td>
<td></td>
<td>1.219***</td>
</tr>
<tr>
<td></td>
<td>(0.058)</td>
<td></td>
<td>(0.068)</td>
<td></td>
<td>(0.068)</td>
</tr>
<tr>
<td>Difference NE †</td>
<td></td>
<td>1.219***</td>
<td>1.257***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.068)</td>
<td>(0.068)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difference CN</td>
<td>1.164***</td>
<td></td>
<td></td>
<td>1.152**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.064)</td>
<td></td>
<td></td>
<td>(0.066)</td>
<td></td>
</tr>
<tr>
<td>Cut-off 1</td>
<td>0.130***</td>
<td>0.151***</td>
<td>0.149***</td>
<td>0.151***</td>
<td>0.138***</td>
</tr>
<tr>
<td></td>
<td>(0.010)</td>
<td>(0.013)</td>
<td>(0.013)</td>
<td>(0.013)</td>
<td>(0.012)</td>
</tr>
<tr>
<td>Cut-off 2</td>
<td>3.015***</td>
<td>2.987***</td>
<td>3.008***</td>
<td>2.992***</td>
<td>3.148***</td>
</tr>
<tr>
<td></td>
<td>(0.186)</td>
<td>(0.198)</td>
<td>(0.200)</td>
<td>(0.199)</td>
<td>(0.223)</td>
</tr>
<tr>
<td>N</td>
<td>2,346</td>
<td>1,948</td>
<td>1,948</td>
<td>1,948</td>
<td>1,843</td>
</tr>
</tbody>
</table>

Notes: Odds ratios displayed. All independent variables are standardized to mean zero and one standard deviation. The † indicates that difference in NE is taken with a negative sign.

...in the dependent variables. So, 1.47 (Model 5) is the change in the odds of moving upward with respect to the parents, over being at the same level or lower, by a standard deviation unit change in the difference in IQ from them. By the proportional odds assumption, this is also the change in the odds of being in the same category or higher over being in a lower category. A test of the proportional odds assumption (Long and Freese, 2014) fails to reject it ($\chi^2(4) = 7.12$, $p = 0.129$), so its use seems reasonable.

The corresponding values are between 1.12 and 1.22 for the other MPQ personality scores. All the skills, soft and hard, have a significant and sizeable effect, in the natural direction; the effect of the change in hard skills is substantially larger than the others.

Determinants of Hard and Soft Skills

Table 12 and Tables A1–A3 in the Online Appendix report the results of the analysis for IQ and the three higher-order MPQ dimensions. The top part of each table reports the estimated coefficients for the fixed effects; the bottom part shows the estimated variance of the random effect at the three levels. The parents’ traits are entered separately, to check for possible differences in roles of the father and mother: the two coefficients are in every case very similar. The results for IQ indicate a strong direct effect of IQ of parents, with an estimated coefficient of approximately 0.3 for each parent’s skill, stable across different models.

Household income has a very small effect, significant only when the variables describing family background are the only predictors. As we have...
### Table 12. Mixed models regression determination of IQ

<table>
<thead>
<tr>
<th></th>
<th>Model 1 b/se</th>
<th>Model 2 b/se</th>
<th>Model 3 b/se</th>
<th>Model 4 b/se</th>
<th>Model 5 b/se</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Estimated coefficients</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Father’s IQ</td>
<td>0.300***</td>
<td>0.302***</td>
<td>0.281***</td>
<td>0.289***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.024)</td>
<td>(0.025)</td>
<td>(0.027)</td>
<td>(0.028)</td>
<td></td>
</tr>
<tr>
<td>Mother’s IQ</td>
<td>0.284***</td>
<td>0.282***</td>
<td>0.277***</td>
<td>0.278***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.024)</td>
<td>(0.025)</td>
<td>(0.025)</td>
<td>(0.026)</td>
<td></td>
</tr>
<tr>
<td>PE</td>
<td></td>
<td>0.058***</td>
<td></td>
<td></td>
<td>0.057***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.018)</td>
<td></td>
<td></td>
<td>(0.018)</td>
</tr>
<tr>
<td>NE †</td>
<td>0.033*</td>
<td>0.034**</td>
<td></td>
<td></td>
<td>0.034**</td>
</tr>
<tr>
<td></td>
<td>(0.017)</td>
<td></td>
<td></td>
<td></td>
<td>(0.017)</td>
</tr>
<tr>
<td>CN</td>
<td>−0.024</td>
<td>−0.025</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.018)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>College of parents</td>
<td></td>
<td></td>
<td>0.224***</td>
<td>0.242***</td>
<td>0.033</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.026)</td>
<td>(0.027)</td>
<td>(0.028)</td>
</tr>
<tr>
<td>Household income</td>
<td></td>
<td></td>
<td>0.092***</td>
<td>0.070</td>
<td>−0.007</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.025)</td>
<td>(0.026)</td>
<td>(0.027)</td>
</tr>
<tr>
<td>Parents’ occ. status</td>
<td></td>
<td></td>
<td>0.078***</td>
<td>0.019</td>
<td>0.007</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.025)</td>
<td>(0.025)</td>
<td>(0.026)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.039*</td>
<td>0.045*</td>
<td>0.004</td>
<td>0.036</td>
<td>0.041*</td>
</tr>
<tr>
<td></td>
<td>(0.023)</td>
<td>(0.023)</td>
<td>(0.023)</td>
<td>(0.023)</td>
<td>(0.023)</td>
</tr>
<tr>
<td><strong>Estimated variances</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Var(family)</td>
<td>0.279***</td>
<td>0.264***</td>
<td>0.253***</td>
<td>0.266***</td>
<td>0.269***</td>
</tr>
<tr>
<td></td>
<td>(0.035)</td>
<td>(0.034)</td>
<td>(0.031)</td>
<td>(0.033)</td>
<td>(0.035)</td>
</tr>
<tr>
<td>Var(twin type)</td>
<td>0.263***</td>
<td>0.267***</td>
<td>0.437***</td>
<td>0.273***</td>
<td>0.261***</td>
</tr>
<tr>
<td></td>
<td>(0.033)</td>
<td>(0.035)</td>
<td>(0.037)</td>
<td>(0.036)</td>
<td>(0.036)</td>
</tr>
<tr>
<td>Var(residual)</td>
<td>0.209***</td>
<td>0.199***</td>
<td>0.209***</td>
<td>0.209***</td>
<td>0.199***</td>
</tr>
<tr>
<td></td>
<td>(0.010)</td>
<td>(0.010)</td>
<td>(0.009)</td>
<td>(0.010)</td>
<td>(0.011)</td>
</tr>
<tr>
<td>(N)</td>
<td>2,346</td>
<td>2,095</td>
<td>2,717</td>
<td>2,328</td>
<td>2,085</td>
</tr>
</tbody>
</table>

*Notes: All independent variables are standardized to mean zero and one standard deviation. The † indicates that NE is taken with a negative sign.*

seen in the discussion following equation (10), an estimated coefficient close to zero in Models 3, 4, and 5 does not prove that the direct effect of income – described in equation (10) by the term \(\pi y_{ij}\) – is negligible. What the estimate in Table 12 shows is the net effect of income, combining the positive direct effect with the negative effect through \(E_{P}[rw(g_{ij})]\). However, the coefficient 9.2 percent in Model 3 establishes an upper bound on the effect size of household income. Similarly, the coefficient of college of parents has a large and significant coefficient (22.4 percent in Model 3) when family background variables are the only predictors, likely capturing the explanatory power of the IQ of the parents.

The fraction of the IQ score variance explained by the predictors is around 25 percent (e.g., the overall \(R^2\) in the panel regression estimate of Model 5 in Table 12 is 0.26).
VIII. Conclusions

We began this investigation with the three questions listed in the introduction. For the first question (the relative contribution of cognitive skills, non-cognitive skills, and family background to educational success and social outcomes later in life), we found that both hard and soft skills have comparable effects on all outcomes considered, both educational and social, and for important features of personal life, such as staying married, financial independence, and legal problems. For educational achievement, the effect size of hard and soft skills is similar. It is interesting to note, however, that this is true in particular for college attainment, and considerably less so in the case of high-school GPA. This is likely to be because college attainment requires a larger set of personal and character qualities, in addition to sheer intelligence, which is more likely to play a crucial role in GPA scores. Most of the variables describing family background are important for educational attainment – both education of parents and family income are (whereas the social and economic status is not). Education of parents can, in part, express the role of intelligence of parents in influencing education both directly and indirectly, through the genetic skill transmission. Income is qualitatively significant, even if the net effect (see Model 5 in Tables 5 and 6), even if the effect size is not large (5 percent in Table 6, Model 5).

There is also a clear and sizeable negative association between male gender and educational outcomes: the odds ratios are reduced by a factor of approximately 0.85 for males (which is a reduction of probability of around 3 percent), even after we control for many of the personality factors that are likely sources of gender differences, such as dedication to school and college work: these factors are in play, as one can see, for example, from Table 3(a), for CN (a 0.52 standardized difference in favor of females), externalizing (0.41 difference), and academic effort (0.45 difference). However, Tables 5 and 6 show that there is an additional component for college attainment, and Table 7 for high-school GPA.

Hard and soft skills are also important for various outcomes beyond education, such as the four we have considered (i.e., financial independence, full-time engagement, current marriage status, and legal problems). However, the specific association between skills and outcomes differs in important ways. For instance, intelligence is important and positive for financial independence, and important and negative for current marriage status. Intelligence is instead irrelevant for legal problems. Education of the individual has an important and distinct role on all outcomes, even after we control for all skills of the twins, all in the natural direction. Education of the parents has an additional, distinct, and sizeable association for legal problems.
As for the second question (what determines upward and downward mobility of children compared to parents), we could examine in detail mobility in educational attainment. We ignore for the moment income, because these data for the children are still preliminary, as the twins are still of a relatively young age. For college attainment instead, we have information for both parents and children, and we can evaluate this. Hard and soft skills both have important roles in mobility. This is particularly clear when we consider the difference in skills of the children compared to those of the parents: all differences are associated with mobility in the natural direction. The more detailed analysis of the skill transmission developed in Section VII, Determinants of Hard and Soft Skills, gives us a way to see how the observable family background and parental investment, unobserved family background (common to both twins), and idiosyncratic random events are associated with individual skills. Relying on the model, we can conclude that the estimates of the coefficients associated with the IQ score of each parent gives a good estimate of the role of genetic transmission. The significant variance associated with the random effect associated with the twin type provides support for this interpretation. The results are very different for hard and soft skills: for soft skills, the estimated relation between parents and children is substantially smaller. The reason for this difference will be the object of further study. A possible interpretation is that intelligence is more stable over the lifetime, compared to other traits (Roberts and DelVecchio, 2000); thus, the age difference between the parents and children at the moment of testing reduces the relation for the latter.

Supporting Information

The following supporting information can be found in the online version of this article at the publisher’s web site.

Online Appendix

References


Hollingshead, A. (1957), *Two Factor Index of Social Position*, Yale University, New Haven, CT.


30 Skills and family background


