MANAGEMENT SCIENCE
Vol. 54, No. 1, January 2008, pp. 167–179
ISSN 0025-1909 | EISSN 1526-5501 | 08 | 5401 | 0167

DOI 10.1287/mnsc.1070.0761

Is the Tendency to Engage in Entrepreneurship Genetic?

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We used quantitative genetics techniques to compare the entrepreneurial activity of 870 pairs of monozygotic (MZ) and 857 pairs of same-sex dizygotic (DZ) twins from the United Kingdom. We ran model-fitting analyses to estimate the genetic, shared environmental and nonshared environmental effects on the propensity of people to become entrepreneurs. We found relatively high heritabilities for entrepreneurship across different operationalizations of the phenomenon, with little effect of family environment and upbringing. Our findings suggest the importance of considering genetic factors in explanations for why people engage in entrepreneurial activity.

Key words: entrepreneurship; twin studies; behavioral genetics
History: Accepted by Wallace J. Hopp, technological innovation, product development, and entrepreneurship; received June 21, 2006. This paper was with the authors $6\frac{1}{2}$ months for 2 revisions.

Introduction

Why do people engage in entrepreneurial activity? Despite the centrality of this question to the field of entrepreneurship, and over 40 years of research that has sought to answer it, researchers have offered incomplete and uncertain answers (Gartner 1988, Shane and Venkataraman 2000). In this paper, we argue that the failure to develop a comprehensive understanding of why people engage in entrepreneurial activity has occurred, in part, because researchers have failed to examine an important category of an explanatory factor—genetics.

Despite a body of empirical evidence that has shown that genetic factors influence a variety of business-related outcomes, from job satisfaction (Arvey et al. 1989) to vocational interests (Betsworth et al. 1994) to work values (Keller et al. 1992), entrepreneurship researchers have not, to date, examined empirically the role of genetic factors in explaining the tendency of people to engage in entrepreneurial activity. Rather, the entrepreneurship literature has assumed that the tendency to engage in entrepreneurial activity is explained by learned individual differences or situational factors.

In this paper, we provide the first empirical test of the effects of genetic factors on the tendency of people to engage in entrepreneurial activity.[1] We employ the methodology of behavioral genetics, which holds that researchers can compare monozygotic (MZ) and dizygotic (DZ) twins to determine if genetic factors influence the propensity of people to engage in an outcome of interest. Because MZ twins share all of their genetic composition and DZ twins share half of their genetic material on average, differences in the concordance between entrepreneurial activity of MZ and DZ twins can be attributed to genetic factors, if one assumes that environmental factors are not systematically different for MZ and DZ twin pairs.

Investigating the influence of genetic factors on the propensity of people to engage in entrepreneurial activity is important for several reasons. First, an understanding of the role of genetic factors will help to improve entrepreneurship research. Genetics offers an explanation for why people engage in entrepreneurial activity that is complementary to the standard ones in the literature of having a certain psychological composition or being present in opportunity-rich situations (White et al. 2006, 2007; Shane and Venkataraman 2000). Because the scholarly

[1] By genetic factors, we mean those factors that are encoded in DNA and transmitted biologically.

field of entrepreneurship has explained only some of the variance in the tendency of people to engage in entrepreneurial activity, examination of additional factors that account for this variance will help scholars to develop a more comprehensive model of why some people and not others become entrepreneurs.

Moreover, empirical investigation of genetic factors will provide richer, more precise explanations for the tendency of people to engage in several important aspects of entrepreneurial activity. For example, genetic research could help to explain to what extent the influence of parental entrepreneurship on children's propensity to become entrepreneurs is influenced by genetic factors transmitted biologically from parent to child, and to what extent it is influenced by environmental factors, such as the role modeling that the parents provide (Sorenson 2007), the transmission of information from parents to children about how to run a business (Aldrich and Kim 2007), and the transfer of resources useful for entrepreneurship (e.g., information, social and financial capital) from parents to children (Sorenson 2007).

Theory Development

The extant literature shows that people who engage in entrepreneurial activity are not randomly determined. A variety of factors are associated with the tendency of people to engage in entrepreneurial activities including psychological attributes, such as the need for achievement (McClelland 1961), overconfidence (Busenitz 1999), locus of control (Evans and Leighton 1989), optimism (Cooper et al. 1988), and risk-taking propensity (Stewart and Roth 2001), and demographic factors, such as education (Bates 1995), employment status (Ritsila and Tervo 2002), age (Bates 1995), marital status (Evans and Leighton 1989), income (Amit et al. 1995), career experience (Evans and Leighton 1989), social ties (Aldrich et al. 1987), and social skills (Baron 2004).

However, no empirical research has examined the effect of genetic factors on the tendency of people to engage in entrepreneurship. This is surprising given the evidence that many aspects of human behavior are influenced by genes (Benjamin et al. 2003, Plomin and Walker 2003) including personality (Ebstein et al. 1996, Benjamin et al. 1996), attitudes (Bouchard et al. 2004), intelligence (Plomin and Spinath 2004), job satisfaction (Arvey et al. 1989), work-related values (Keller et al. 1992), and interests (Lykken et al. 1993). If genetic factors influence other aspects of human behavior, they are likely to influence the tendency of people to engage in entrepreneurial activity as well.[2]

Genetic factors might influence the tendency of people to engage in entrepreneurship through a variety of complementary mechanisms. First, genes might have direct effects on chemical mechanisms in the brain that predispose people with that genetic composition to engage in entrepreneurial activity. Genes provide instructions for the creation of proteins out of amino acids. If a gene that codes for the creation of a particular protein is missing, then the chemical reaction that it is designed to facilitate will not occur as efficiently. If that chemical reaction controls brain activity, it can influence behavior. For example, the Taq A1 allele[3] of the DRD2 gene has been shown to be more prevalent among excessive gamblers than the general population because the gene affects sensations of pleasure in response to risk taking (Comings et al. 1996). Because entrepreneurship involves risk taking, it is possible that people with this variant of the DRD2 gene are more likely to engage in entrepreneurial activity than other people because the gene increases the pleasure that they obtain from taking risks.

Second, genes might predispose people to develop individual attributes that affect the tendency of people to engage in entrepreneurship (White et al. 2006, 2007). For example, extraversion is a personality trait that incorporates several attributes, including sociability, gregariousness, talkativeness, and exhibitionism (Barrick and Mount 1991). Extraversion increases the likelihood that people will engage in entrepreneurship because it facilitates many skills, such as selling, that are important to it (Baron and Markman 2003). Moreover, extraversion is heritable (Bouchard and Loehlin 2001, Eaves et al. 1989, Jang et al. 1996, Riemann et al. 1997) and is related to the long alleles of the DRD4 exon III repeat gene (Benjamin et al. 1996). Thus, genes might affect the tendency of people to engage in entrepreneurial activity by influencing their level of extraversion.

Third, genes might affect the tendency of people to select into environments more favorable to entrepreneurial activity, a phenomenon called *gene-environment correlation* (Plomin et al. 1977, Kendler

[2] We do not reject the possibility that other factors, such as the exogenously determined external environment, also influence the development of the characteristics that lead some people to engage in entrepreneurial activity. Moreover, we do not argue that genes *determine* who engages in entrepreneurial activity in the way that specific genes *determine* whether or not people will develop diseases, such as Huntington's disease. Rather, we argue that genes increase the probability that people will engage in entrepreneurial activity (Plomin et al. 1990). As Plomin et al. (1990, p. 376) explained, "Genetic effects on behavior are not deterministic in the sense of a puppeteer pulling our strings. Genetic influences imply probabilistic propensities rather than hard-wired patterns of behavior."

[3] An *allele* is any one of a number of possible DNA codings of the same gene.

and Eaves 1986). Because genes lead people to select their environments (Scarr 1992), environmental factors are nonrandomly distributed among people of different genetic make-up (Neale and Maes 2002). For example, gene-environment correlations might influence the tendency of people to engage in entrepreneurial activity by affecting their educational choices (Taubman 1976, Lichtenstein et al. 1992, Tambs et al. 1989, Behrman and Taubman 1989). People are more likely to engage in entrepreneurial activity if they are more highly educated because education provides the background knowledge necessary to notice new business opportunities (Shane 2000), and information and skills that increase the expected returns to entrepreneurial activity (Clouse 1990). Genes affect the level of education that people obtain (Behrman and Taubman 1989, Tambs et al. 1989). Thus, genes might affect the tendency of people to engage in entrepreneurship by influencing their level of education.

Fourth, genes might make some people more sensitive than others to environmental stimuli that increase the likelihood of engaging in entrepreneurial activity. This tendency, called *gene-environment interaction*, means that a person with the relevant gene displays a greater reaction to the environmental stimulus than a person without that gene (Plomin et al. 1977, Rowe 2003, Moffitt et al. 2005). For example, the dopamine D4 receptor gene, which regulates the level of dopamine in the brain (Ebstein et al. 1996, Benjamin et al. 1996), has been shown to increase the salience of information (Berridge and Robinson 1998, Volkow 2004). The identification of new business ideas is affected by the salience of information to the person receiving it (Gaglio and Katz 2001, Shane 2000). People with the DRD4 gene might be more sensitive than others to the stimulus of information about potential business opportunities. That is, the DRD4 gene might interact with information about opportunities to increase the likelihood that a person will identify a new business idea, and therefore increase the probability that the person will engage in entrepreneurship.

These four mechanisms, through which genes influence social outcomes, suggest that the tendency of people to engage in entrepreneurship might be at least partially heritable. Therefore, we hypothesize: *Genetic factors have a statistically significant and substantive effect on the propensity of people to engage in entrepreneurship.*

Methodology

Twin Studies

The natural experiment of twins allows us to measure whether the tendency of people to engage in entrepreneurship has a genetic component. The experiments are based on the comparison of MZ twins, which are created when a single sperm fertilizes a separate egg, and therefore share 100% of their genetic make-up, and DZ twins, which are created when two separate eggs are fertilized by two separate sperm, and share, on average, 50% of their segregating genes.

Comparing the similarity and difference in entrepreneurship between the two types of twins provides insight into the proportion of variance in entrepreneurship that is explained by genetic factors. Because MZ twins share all of their genetic make-up and DZ twins share, on average, 50% of their segregating genes, greater MZ than DZ twin concordances in entrepreneurship would indicate that genetic factors are important. However, if the tendency to engage in entrepreneurship is explained solely by environmental factors, then no difference between MZ and DZ twin concordances in entrepreneurship should be observed.

Twin studies depend on the assumption that MZ and DZ twins experience equivalent environments. For violation of this assumption to occur, environmental factors must treat MZ twins more similarly than DZ twins and the similarity in treatment must make a difference in the phenotype under study. The equal environments assumption has been tested extensively and many sources now confirm the robustness of this assumption (Scarr and Carter-Saltzman 1979, Bouchard and Propping 1993, Kendler et al. 1993, Hettema et al. 1995, Carey 2003). Studies of MZ and DZ twins raised together and apart have shown that the MZ twins raised apart are consistently more similar than DZ twins raised together (Bouchard 1998, Bouchard et al. 1990). In addition, studies of twins reared apart and together and studies of biologically unrelated people reared in the same household have shown that the rearing environment explains very little variance in most social outcomes (Bouchard et al. 1990, Plomin and Daniels 1987). Furthermore, many parents tend to randomize the environmental treatment of their children. Many are misinformed or make erroneous evaluations about the zygosity of their twins, leading some parents to raise their DZ twins as MZ twins and other parents to treat their MZ twins as DZ twins. Some parents accentuate the similarity of their DZ offspring by making certain that they wear the same clothes and have the same hairstyles, while others deliberately try to individualize their MZ twins. As a result, researchers observe little systematic difference in the treatment of MZ and DZ twins by their parents. In fact, studies have shown that in cases where parents made erroneous conclusions about the zygosity of their twins, it was actual, rather than perceived zygosity that predicted similarity between twins (Scarr and Carter-Saltzman 1979).

Given this evidence, Lykken et al. (1993) explain that researchers can safely assume that pairs of MZ and DZ twins, on average, face the same environments, and heritability can be estimated conservatively from samples of twins reared together.

Sample

Our sample is drawn from the TwinsUK registry—the national volunteer twin register in the UK—initially recruited through a national media campaign (www.twinsuk.ac.uk; see Spector et al. 1996). All were healthy volunteers, comparable to age-matched singletons (Andrew et al. 2001). The majority was born in the British Isles (96% and 98% of MZ and DZ twins, respectively) and was Caucasian (97% and 96% of MZ and DZ twins, respectively). Over 90% of the sample was female (this is because the twins were initially recruited to examine bone density and osteoporosis, a disease which occurs primarily in females). All the twins were twins reared together and there were no opposite-sex DZ twins in the sample. Zygosity of each twin pair was determined by using a standard validated questionnaire, which has an accuracy of over 95% (Martin and Martin 1975, Peeters et al. 1998), and, where necessary, through multiplex DNA fingerprinting using variable tandem repeats, which has a 99.7% accuracy (Singer et al. 2005).

In 1999, each subject was sent a postal questionnaire (response rate of 68%) that focused mainly on health-related issues and medical history. For example, it included questions on osteoarthritis and osteoporosis, asthma, skin conditions, and general medical history. It also included some "lifestyle" questions related to alcohol consumption, smoking, and physical activity. Given this focus, respondents were unaware of the hypothesis of this study when deciding whether or not to respond to the survey. The sample consisted of 2,532 twins comprising of 607 pairs of MZ and 657 pairs of same-sex DZ twins.

Of particular interest to this study, the questionnaire elicited information on demographic characteristics, including marital status, ethnicity, whether they were born in the British Isles, household income, educational level, and self-employment status. In 2006, we sent an additional postal questionnaire to the twins, which elicited information using additional operationalizations of entrepreneurship. The 2006 sample consisted of 3,454 twins comprising of 870 pairs of MZ and 857 pairs of same-sex DZ twins.

Table 1 shows the questionnaire items used in this study.

Measures of Entrepreneurship

The research literature does not agree on the definition of entrepreneurship. Given these differences, we seek convergent validity for our argument by examining several different operationalizations common in the literature. These include (1) self-employment (Amit et al. 1995, Evans and Leighton 1989, Taylor 1996, Burke et al. 2000, Van Praag and Cramer 2001, Parker 2004), which we operationalize with the questions: "Are you self-employed?" and "In your working life, how long have you been self employed?"; (2) starting a new business (Gartner 1988, Mesch and Czamanzki 1997, Delmar and Davidsson 2000), which we operationalize with the questions: "Have you ever started a new business?" and "In your working life, how many new businesses have you started?" (this latter question is measured on the following scale: "one"; "two"; "three"; "four or more"); (3) being an owner-operator of a company (Hull et al. 1980, Ahmed 1985, Bitler et al. 2005), which we operationalize with the questions: "Have you ever been an owner-operator of a company?" and "In your working life, how many companies have you been an owner–operator of?" (this latter question is measured on the following scale: "one"; "two"; "three"; "four or more"); and (4) engaging in the firm start-up process (Reynolds et al. 2004, Ruef et al. 2003, Delmar and Shane 2003), which we operationalize with the questions: "Have you taken any actions toward the creation of a new business?" and "In your working life, for how many new business ideas have you taken any actions toward the creation of a new business?" (this

Table 1 Questionnaire Items

Variables	Items
Self-employment	Working as self-employed (yes = 1)
Years self-employed	How long have you been self-employed?
Owner-operator	Have you been an owner-operator of a company?
Businesses owned and operated	How many companies have you been an owner-operator of?
Business founder	Have you started a new business?
Businesses founded	How many new businesses have you started?
Engaged in start-up effort	Have you taken any actions toward the creation of a new business?
Start-up efforts undertaken	For how many new business ideas have you taken any actions toward the creation of a new business?
Attitudes toward entrepreneurship	Please identify your attitudes toward entrepreneurship as a career (an entrepreneur is a person who starts a new business venture)
Race	Which of the following best describes your ethnic origin? Caucasian, Asian, Oriental, Black, or other.
Immigrant status	Were you born in the British Isles? (yes = 1)
Marital status	What is your marital status? (married = 1)
Qualification	12-point scale ranging from "no qualification" to "university degree."
Income	What is your total yearly income before taxes (7 scales ranging from "less than £5000" to "over £50000")—subsumed into 3 scales to conserve degrees of freedom in the analysis.
Gender	(1 = female; 0 = male)
Age	Age of the respondents

latter question is measured on the following scale: "one"; "two"; "three"; "four or more").

Attitudes Toward Entrepreneurship
To identify the mechanism through which genetic factors operate, we also examined the respondents' attitudes toward entrepreneurship through a Likert scale item that asked them to indicate, on a scale from one (a very good career) to five (a very bad career), their view of entrepreneurship as a career.

Structural Equation Modeling
Quantitative genetic theory holds that three unobservable components can be combined additively to explain the variance in a phenotype (in our case, entrepreneurship): genetic effects (A), shared environmental effects (or the environmental factors that people in the same family have in common) (C), and nonshared environmental effects (the environmental effects that are unique to an individual) (E).[4] These three components generate the basic ACE model of behavioral genetics.

Following the standard approach in behavioral genetics, we use quantitative genetic modeling techniques (which are based on structural equation models fit to a data set) to estimate the genetic and environmental contributions to twin resemblance in entrepreneurship (Neale and Cardon 1992, Falconer 1989, Sham et al. 1994).[5] These techniques allow us to estimate the magnitude of the genetic and environmental influences and the size of the errors of these estimates, and test the fit of the model (Plomin et al. 1990).[6]

Figure 1 Path Model for Entrepreneurship Status for Twins 1 and 2

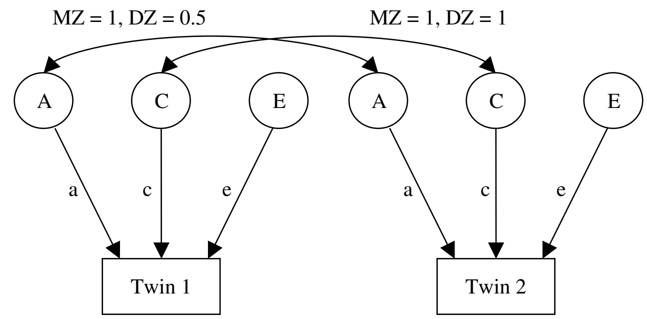

Figure 1 shows the path models we test graphically. Observed entrepreneurship status is represented by the rectangles (Twins 1 and 2). Latent factors, which the study estimates, are represented by the circles. A, C, and E are the additive genetic, common environmental, and unique environmental influences, respectively. (Because monozygotic twins share the same genes, and dizygotic twins share half their additive genes, the correlation between the latent additive genetic factors is 1.0 for MZs and 0.5 for DZs. Because monozygotic and dizygotic twins share the same common environment, the correlation between the latent common environmental factors is 1.0 for MZs and DZs.)[7] The regression coefficients of the observed variables on the different latent factors are shown in lowercase letters: *a* denotes the additive genetic effect, *c* the common environmental effect, and *e* the unique environmental effect.

The models that we use are represented by the following structural equations:

$$P_{ij} = aA_{ij} + cC_{ij} + eE_{ij},$$
$$V_p = a^2 + c^2 + e^2 = 1,$$

[4] By environment, we mean all nongenetic effects (including the biological effects of the uterus, the home in which people are raised, and the social environment in which people live and work) on entrepreneurship.

[5] Maximum likelihood estimation of covariance structure provides the best statistical method for disentangling genetic from environmental variance in behavior (Cherny et al. 1992, Sham 1998). Although regression methodology for the analysis of twins has been proposed (Sham et al. 1994), there are distinct advantages in using the more general framework of structural equation modeling (Martin and Eaves 1977, Sham et al. 1994, Sham 1998). First, the hypothetical causal relationships which are made explicit in a structural equation model are only implicit in the regression models (Sham 1998). Consequently, if we simply regressed the behaviors of twin one on the behaviors of twin two to see if there was a differential risk for MZ and DZ twins, this would only provide a test of genetic aetiology, not latent heritability. To estimate latent heritability, we need structural equation modeling which assumes that all polygenes act in an independent additive manner to provide a hypothetical normal distribution of risk underlying a binary trait. Second, structural equations permit nested submodel comparisons, which make possible identification of the most parsimonious model (Bulik et al. 2000). Third, the regression approach requires the double entry of twins, which creates problems with interpretation of the coefficients because the cotwins are not independent of each other (Turkheimer et al. 2005). Fourth, the regression approach requires constrained estimation to avoid nonsensical estimates (e.g., negative proportions of variance or estimates exceeding unity) (Cyphers et al. 1990). Fifth, the regression approach faces problems with heteroskedasticity, arising from the fact that DZ twins are expected to have a greater residual variance than MZ twins, in the presence of a genetic component (Sham 1998).

[6] McGue et al. (1987) showed that model-fitting techniques provide parameter estimates that are robust to violations of normality assumptions.

[7] The shared and nonshared environments represent the environmental subcomponents of variance in a phenotype; the nonshared (or unique) environment refers to environmental influences that contribute to differences between family members, while the shared (or common) environment refers to environmental factors that make family members similar (Plomin et al. 2001, Carey 2003). In other words, the nonshared environmental influences which are uncorrelated across siblings (Rowe 1994) capture "the extent to which idiosyncratic experiences make relatives different," while the shared environment—things like parenting style and family socio-economic status if these increase twin similarity—captures "the extent to which being raised together makes relatives similar" (Carey 2003, p. 305).

where P is the phenotype of the ith individual in the jth pair ($i = 1, 2$; $j = 1, \ldots, n$; all variables are scaled as deviations from zero), and V_p is the total phenotypic variance of the population representing the sum of additive genetic (a^2), common environmental (c^2), and unique environmental variance (e^2).

These models generate the following predicted variance-covariance matrices for the ACE models:

$$\text{Cov MZ:}\quad \begin{matrix} \\ \text{Twin 1} \\ \text{Twin 2} \end{matrix} \begin{matrix} \text{Twin 1} \qquad \text{Twin 2} \\ = \begin{pmatrix} a^2 + c^2 + e^2 & a^2 + c^2 \\ a^2 + c^2 & a^2 + c^2 + e^2 \end{pmatrix} \end{matrix},$$

$$\text{Cov DZ:}\quad \begin{matrix} \\ \text{Twin 1} \\ \text{Twin 2} \end{matrix} \begin{matrix} \text{Twin 1} \qquad \text{Twin 2} \\ = \begin{pmatrix} a^2 + c^2 + e^2 & \frac{1}{2}a^2 + c^2 \\ \frac{1}{2}a^2 + c^2 & a^2 + c^2 + e^2 \end{pmatrix} \end{matrix}.$$

We use maximum likelihood methods to generate parameter estimates, which are similar to regression coefficients, and can be interpreted as estimates of the variance in the genetic (A), shared environmental (C), and nonshared environmental effects (E) (although the coefficient for nonshared environmental effects includes measurement error).

The genetic effect measured in the model serves as our key coefficient of interest. If entrepreneurship is completely genetically determined, then the estimate of the effect of the variance in the genetic effect would be 1.00. In contrast, if a phenotype is completely environmentally determined, then the estimate of the effect of the variance in the genetic effect would be zero.

The fit of the overall model is estimated using a chi-square goodness-of-fit test (a perfect fit is 1.00), with a nonsignificant chi-square test showing that the model fits the data well (Betsworth et al. 1994). The contribution of A, C, and E to the total variance is evaluated by removing each of them in a nested submodel and testing the level of fit of that model relative to the overall model.

Choice of Models

To ascribe sources of variation to the ordinal measures of entrepreneurship (the number of businesses started, number of businesses that are owner-operated, number of years self-employed, and number of new business start-up efforts), we used polychoric models based on asymptotically distribution free weighted least squares (Browne 1982, 1984; Joreskog 1990; Neale 2004). To ascribe sources of variation to the dichotomous measures of entrepreneurship (ever started a business, was ever a business owner-operator, was ever self-employed, and ever engaged in the business start-up process), we used liability threshold models in which the presence or absence of entrepreneurship is based on the assumption of an underlying continuous liability and that the "trait" is expressed when the liability exceeds a threshold value (Sham 1998). (See the electronic companion for further details.)[8]

The ability to make strong causal statements about genetic factors requires a correction for potential factors that can lead to a correlation of twin scores (Cropanzano and James 1990). Therefore, we adjust the model for potential confounders associated with self-employment: age, education, marital status, income, race, and immigrant status. If genetic factors also predict factors that exert an environmental influence on entrepreneurship, then the effect of these factors on self-employment could be the result of either genetic or environmental factors, and the genetic factors cannot be accurately estimated. We follow previous research (e.g., Mohammed et al. 2003, Hakim et al. 2004) in adjusting the model for potential confounders to see how estimates of variance components varied once confounders were included in the model.

Table 2 Summary Statistics

	Monozygotic twins	Dizygotic twins	p-value
Age (years)	43	44	0.112
Female	92%	94%	0.134
Currently self-employed	10%	9%	0.565
Years self-employed	0.67	0.69	0.656
Owner-operator	0.16	0.16	0.600
Companies owned and operated	0.25	0.25	0.990
Business founder	0.22	0.23	0.673
Businesses founded	0.36	0.35	0.601
Engaged in start-up effort	0.25	0.26	0.554
Start-up efforts undertaken	0.48	0.48	0.984
Attitudes toward entrepreneurship	2.52	2.51	0.926
Caucasian	97%	96%	0.394
Born in British Isles	96%	98%	0.100
Married	61%	63%	0.351
Qualification 5	5%	5%	0.403
Income <15 K	13%	16%	0.164
Income 15 K–25 K	23%	26%	0.124
Income >25 K	64%	58%	0.025

Results

Basic demographic data for the MZ and DZ twins are shown in Table 2. The two groups were well matched for factors associated with entrepreneurship, with only statistically significant difference between MZ and DZ twins (at the $p < 0.10$ level) having income over 25,000 pounds. There were no statistically significant differences between the two groups of twins on measures of self-employment, owner-operator, company founding, or engaging in the business formation process (Levene's test, which was used for the

[8] An electronic companion to this paper is available as part of the online version that can be found at http://mansci.journal.informs.org/.

Table 3 Correlations Between the Various Measures of Entrepreneurship

Variables	1	2	3	4	5	6	7
1. Businesses founded							
2. Businesses owned and operated	0.64						
3. Years self-employed	0.60	0.51					
4. Start-up efforts undertaken	0.69	0.48	0.45				
5. Business founder	0.85	0.51	0.62	0.61			
6. Owner-operator	0.53	0.85	0.51	0.41	0.83		
7. Self-employment	0.58	0.48	0.88	0.43	0.87	0.81	
8. Engaged in start-up effort	0.61	0.41	0.47	0.85	0.89	0.72	0.73

nondichotomous measures, also indicated equality of variances between the groups). A correlation table between the various measures of entrepreneurship is provided in Table 3.

Table 4 predicts whether the respondent was currently self-employed. The chi-square test for goodness-of-fit for the model, the Akaike information criterion (AIC) (Akaike 1987), and the root mean square error of approximation (RMSEA) showed that the best-fitting model to explain the variance in self-employment included additive genetic and environmental factors. Estimates of the genetic and environmental variance components revealed that 48% of the variance in the propensity to become self-employed is explained by genetic factors. None of the variance in self-employment can be attributed to shared environmental factors, while 52% can be attributed to nonshared environmental factors plus measurement error.

If measures of entrepreneurship are correlated with gender, then estimates of genetic effects will be upwardly biased because all MZ twins share the same gender (McGue and Bouchard 1984). Therefore, we reran our analysis on just the female respondents. As Table 5 shows, our results for whether or not the respondent is self-employed remain qualitatively the same.

We also reran the analysis adjusting the model for potential confounders—income, education, marriage, age, race, and immigrant status—that have been shown to be associated with entrepreneurship (Aldrich and Kim 2007, Shane 2003). Consequently, differences in these dimensions across MZ and DZ twins might explain some of the differences in the concordance of self-employment between the two types of twins. Table 6 shows that adjusting for these potential confounders does little to reduce the heritability estimates for self-employment, which drop only to 0.41 when these variables are included.

We also examined the convergent validity across different measures of entrepreneurship. Table 7 shows the results of our analysis. Across the seven additional operationalizations of entrepreneurship, we found that the best model to explain the variance in entrepreneurship included additive genetic and unshared environmental factors, and heritabilities that ranged between 0.37 and 0.42.[9] Combining these results with the heritability that we found for our measure of self-employment, we conclude that there is convergent validity for the heritability of entrepreneurship. Moreover, under the assumption that genetic factors are exogenous (genetic factors can affect entrepreneurship, but entrepreneurship cannot affect genetic factors), we can attribute causality to the relationship. That is, genetic factors make some people more likely than others to become entrepreneurs.

We also examined the respondents' attitude toward entrepreneurship as a career. This analysis showed that the best-fitting model to explain the variance in attitudes included shared and unshared environmental factors. None of the variance in attitudes toward entrepreneurship as a career was explained by genetic factors, indicating that the mechanism through which these factors affect the tendency to become an entrepreneur is not through attitudes toward the vocation.

Discussion

We used quantitative genetics techniques to compare the entrepreneurial activity of a sample of MZ and same-sex DZ twins from the United Kingdom. We ran model-fitting analyses to estimate the genetic, shared environmental, and nonshared environmental effects on the propensity of people to become entrepreneurs. We found qualitatively similar heritability estimates across different operationalizations of entrepreneurship, which were of similar magnitude to that obtained in many studies of other social outcomes (MacGregor 2000). Moreover, our estimates of heritability remained high even after we adjusted the model for potential confounders such as gender, age, income, education, marital status, race, and immigrant status.

In short, our results indicate that genetic factors influence the tendency to become an entrepreneur.

[9] Following the suggestion of a reviewer, we derived heritability estimates on a scale based on the ordinal measures of entrepreneurship used in this study. First, we conducted a factor analysis on the measures, which yielded a single factor. All loadings on the factor were greater than 0.80, the eigenvalue was 2.70, and the factor captured 68% of the variance. The Kaiser-Meyer-Olkin measure of sampling adequacy was 0.77 and Bartlett's test of sphericity was 5,668.94 ($p < 0.001$). The scale composed of the items had a Cronbach's alpha of 0.80. Second, we generated heritability estimates for this composite scale and used the AIC, RMSEA, and chi-square statistic to identify the best-fitting model. We found that the best fit was with an AE model which had a heritability of 0.33 (AIC $= -3.17$; RMSEA $= 0.02$; $p = 0.31$), further corroborating the findings of the study.

Table 4 Genetic Modeling Analysis to Predict Currently Self-Employed

Model	A (95% CI)	C (95% CI)	E (95% CI)	χ^2	df	*p*-value	AIC	RMSEA
ACE	0.48 (0.17 to 0.63)	0 (0 to 0.23)	0.52 (0.37 to 0.69)	4.53	3	0.21	−1.47	0.01
CE	—	0.34 (0.20 to 0.47)	0.66 (0.53 to 0.80)	11.74	4	0.02	3.74	0.05
AE	0.48 (0.31 to 0.63)	—	0.52 (0.37 to 0.69)	4.53	4	0.34	−3.47	0.01

Note. A, additive genetic; C, common environment; E, unique environment.

However, they do not indicate that entrepreneurship is genetically determined. Although our measures of environmental factors include measurement error (given our study design), their size suggests that they explain much of the variance in entrepreneurial activity, providing strong evidence of the effect of environmental factors on the propensity to become an entrepreneur.

Limitations

This study does not identify the genes that influence the tendency to engage in entrepreneurship. Therefore, we cannot know which genes matter, how many genes matter, or the relative importance of different genes to entrepreneurship. In fact, such information cannot be ascertained through twin studies, such as this one, but require molecular genetics research that examines specific genes. Nevertheless, our results indicate the value of conducting molecular genetics studies of entrepreneurship.

Second, this study does little to specify the mechanism through which genetic factors influence the tendency to become an entrepreneur. Our evidence could be explained by direct genetic effects on brain physiology, leading to chemical rewards in response to actions that fit a genetic predisposition. They could also be explained by genetic influences on the predisposition to have other attributes, such as intelligence or social skills, which increase the propensity to become an entrepreneur. It is also possible that environmental factors mediate the effects of genetic factors on the tendency become an entrepreneur. Alternatively, people with certain genes might be more likely than others to become entrepreneurs when confronted with a favorable environmental stimulus.

Data availability limited the variables that could be included in our structural equation models. As a result, we could only examine income, education, marriage, age, gender, race, and immigrant status. The inclusion of these mediating variables changed our estimates of the heritability of entrepreneurship very little, suggesting that these variables are not the mediators through which genetic factors operate, and that future research will be necessary to identify those mechanisms.

Third, our study cannot be directly generalized to males because the twin population we studied is overwhelmingly female. This gender imbalance exists for historical reasons (many of the initial medical conditions that the study was designed to address, such as osteoporosis, are more common among women than among men, leading to a focus on collecting data from women). While we have no reason to believe that the results are gender specific (our analyses using females only and males and females yielded identical estimates of heritability), we cannot conclude from our evidence that genetic factors influence the likelihood that men become entrepreneurs.

Fourth, like almost all twin studies in behavioral genetics, this study assumes that there is no assortative mating. If this assumption was shown to be untrue, then the estimates of the heritability shown in this study would be overstated. Assortative mating occurs when people with similar phenotypes tend to have children, leading the genetic characteristics of the parents to be positively correlated (Carey 2003). While we have no empirical evidence to suggest that entrepreneurs are more likely to have children with other entrepreneurs than they are to have children with nonentrepreneurs, such evidence would violate the no-assortative-mating assumption, and lead our estimates of the heritability of entrepreneurship to be too high.

Finally, this study assumes that MZ twins are no more likely to imitate the behaviors of their cotwins than DZ twins. If this assumption was untrue, then MZ twins could be more likely than DZ twins to be entrepreneurs if their cotwins were entrepreneurs for both genetic and nongenetic reasons. If the MZ twins were more likely to imitate the behavior of their cotwins for genetic reasons, our results would be unaffected, but if the MZ twins were more likely

Table 5 Genetic Modeling Analysis to Predict Current Self-Employment for Females Only

Model	A (95% CI)	C (95% CI)	E (95% CI)	χ^2	df	*p*-value	AIC	RMSEA
ACE	0.48 (0.14 to 0.63)	0 (0 to 0.27)	0.52 (0.37 to 0.69)	5.48	3	0.14	−0.52	0.02
CE	—	0.35 (0.20 to 0.49)	0.65 (0.51 to 0.80)	11.79	4	0.02	3.79	0.05
AE	0.48 (0.31 to 0.63)	—	0.52 (0.37 to 0.69)	5.48	4	0.24	−2.52	0.01

Note. A, additive genetic; C, common environment; E, unique environment.

Table 6 **Genetic Modeling Analysis for Self-Employment Adjusting for Income, Qualification Level, Marital Status, Age, Born in the British Isles and Caucasian**

Model	A (95% CI)	C (95% CI)	Difference in χ^2	Difference in df
ACE	0.67 (−0.03 to 1.37)	−0.23 (−0.82 to 0.36)	—	—
CE	—	0.29 (0.12 to 0.46)	7.36	1
AE	0.41 (0.20 to 0.62)	—	1.21	1

Note. A, additive genetic; C, common environment; E, unique environment.

to imitate the behavior of their cotwins for nongenetic reasons, then our estimates of the heritability of entrepreneurship would be overstated. To rule out the effect of nongenetic mimicry conclusively, we would need data on MZ and DZ twins reared together and apart, thereby ensuring that some portion of the twins were unaware of the entrepreneurial decisions of their cotwins. Unfortunately, we do not have these data.

However, we believe that imitation for nongenetic reasons is an unlikely explanation for the higher concordance for entrepreneurship between pairs of MZ twins than between pairs of DZ twins. Previous research on MZ and DZ twins indicates that MZ twins reared together are no more likely than MZ twins reared apart to make the same choices as their cotwins. For example, MZ twins reared together and MZ twins reared apart are equally likely to smoke if their cotwin smokes (Kendler et al. 2000), indicating that knowledge of the cotwin's smoking decision does little to affect the likelihood that an MZ twin will smoke, and showing that nongenetically driven imitation cannot be the source of the concordance. If there is little evidence that MZ twins imitate the easy-to-undertake activities of their cotwins, like smoking, then it is unlikely that MZ twins will be more likely than DZ twins to imitate the difficult-to-undertake entrepreneurial decisions of their cotwins for nongenetic reasons.

Furthermore, for the alternative explanation of the greater likelihood that MZ twins imitate the entrepreneurial choice of DZ twins for nongenetic reasons to explain the higher level of concordance for entrepreneurship between MZ twins, imitating the behavior of a cotwin would have to be something that MZ twins consider to be more desirable than DZ twins. However, previous research indicates the opposite (Pearlman and Ganon 2000). MZ twins are more likely than DZ twins to choose behaviors to differentiate themselves from their cotwin. If that were the case for entrepreneurship as well, our heritability estimates would actually be understated, not overstated.

Research Implications

Our findings suggest the value of broadening the theoretical frameworks to explain entrepreneurship to consider the effects of genetic factors. Extant research does not explain all of the variance in the tendency of people to become entrepreneurs, and examination of genetic factors offers the potential to account for some of this unexplained variance (Aldrich and Kim 2007).

Second, our results offer the potential to reinvigorate a longstanding, but not universally agreed upon, aspect of entrepreneurship research: the role of individual differences in the tendency of people to become entrepreneurs. Although some entrepreneurship researchers consider individual differences to be an important explanatory factor in who becomes an entrepreneur (Shane and Venkataraman 2000), many researchers believe that individual differences are unimportant (Gartner and Carter 2003) or even a dead end (Aldrich and Wiedenmeyer 1993). As a result, in recent years, the field of entrepreneurship has tended to focus less on the role of individuals and more on the role of environmental conditions to explain the tendency of people to become entrepreneurs (Thornton and Flynn 2003). Our results indicate that individual differences matter considerably, and offer an avenue for invigorating research on the role of individual differences in entrepreneurship.

Table 7 **Summary of the Results of the Genetic Modeling Using Different Measures of Entrepreneurship**

Dependent variables	A (95% CI)	C (95% CI)	E (95% CI)
Years self-employed	0.39 (0.24 to 0.44)	—	0.61 (0.56 to 0.66)
Owner operator	0.37 (0.25 to 0.49)	—	0.63 (0.51 to 0.75)
Number of companies owned and operated	0.37 (0.32 to 0.42)	—	0.63 (0.58 to 0.68)
Having started a business	0.41 (0.31 to 0.51)	—	0.59 (0.49 to 0.69)
Number of businesses started	0.42 (0.37 to 0.47)	—	0.58 (0.53 to 0.63)
Engaged in start-up effort	0.41 (0.31 to 0.50)	—	0.59 (0.50 to 0.69)
Number of start-up efforts	0.42 (0.37 to 0.47)	—	0.58 (0.53 to 0.63)
Attitudes toward entrepreneurship as a career	—	0.18 (0.13 to 0.23)	0.82 (0.77 to 0.87)

Notes. A, additive genetic; C, common environment; E, unique environment. The results for the best-fitting model for each variable are shown.

For example, our results suggest that genetic factors may account for the differences in testosterone levels between entrepreneurs and nonentrepreneurs, and thus might affect the tendency to become an entrepreneur through physiological mechanisms (White et al. 2006).

Third, our results inform an important research issue, which is concerned with the mechanism through which parental entrepreneurship influences children's propensity to become entrepreneurs (Aldrich and Kim 2007). There is strong evidence across a wide range of studies that the likelihood of becoming an entrepreneur increases with parental entrepreneurship (Fairlie 1999, De Wit and van Widen 1989, Taylor 1996, Burke et al. 2000, Uusitalo 2001). The prevailing explanations for this empirical pattern are (1) that the children of the entrepreneurs learn more about entrepreneurship than the children of nonentrepreneurs from the information gathered either actively or passively during their childhood, (2) have greater exposure to entrepreneurial role models, or (3) receive more resources useful to entrepreneurship from their parents, such as information, social, and financial capital (Aldrich and Kim 2007, Krueger 1993, Sorenson 2007). While our study does not negate these mechanisms, it suggests that the intergenerational transmission of entrepreneurship is also influenced by genetic factors passed from parents to children.

Fourth, our findings contribute to a literature on the effect of genetic factors on career choice, vocational interests, and work-related behavior. Segal's (1999a, 1999b; 2005) case studies provide fascinating examples of identical twins choosing similar occupations. In addition, behavioral genetics studies have consistently pointed to a substantial genetic influence on vocational interests (McGue and Bouchard 1998, Gottfredsson 1999, Moloney et al. 1991, Betsworth et al. 1994), job satisfaction (Arvey et al. 1989), and work-related values (Keller et al. 1992). Our study complements this literature by showing that genetic factors affect an important aspect of work-related behavior—the choice to become an entrepreneur.

Finally, our findings contribute to an emerging literature that adopts a "biosocial model" of behavior (White et al. 2007), which brings together both biological and sociological explanations for entrepreneurial activity. In an insightful study, White et al. (2007) found that testosterone was positively associated with entrepreneurship only in the presence of a family business background. Our paper supports White et al.'s findings, but suggests that social and learning processes are not the only mechanism through which the family business background might influence children's tendency to become entrepreneurs; the transmission of genes passed from entrepreneurial parents to their children also affects that tendency. Our finding of a genetic effect, but no shared environmental influences on the tendency to engage in entrepreneurial activity, means that the net effect of being raised in the same family does not, on average, increase the similarity of siblings in their tendency to engage in entrepreneurial activity, but that parents who own a family business are more likely to pass on the genes that increase the predisposition to entrepreneurship than parents who do not own a family business.

Managerial Implications

Our finding that the entire environmental influence on entrepreneurship (regardless of operationalization of the phenomenon) was accounted for by nonshared environmental factors has important implications for corporate venturing and the creation of spin-off companies. Under the assumption (supported by the literature) that a significant component of the nonshared environment comes from a person's work environment, this result suggests that companies can influence the likelihood that their employees will become entrepreneurs by the type of work environment that they provide. Thus, companies can influence the tendency of their employees to engage in two activities of strategic importance: the tendency of employees to engage in corporate venturing (the creation of new companies by established companies) and the level of spin-off activity (people quitting companies to pursue business opportunities rather than pursuing them on behalf of their employers).

Second, our finding that attitudes toward entrepreneurship as a career are not heritable has implications for entrepreneurship education. Attitudes toward entrepreneurship influence the likelihood that a person becomes an entrepreneur (Kolvereid 1996, Luhtje and Franke 2003, Souitaris et al. 2007). Because these attitudes are not influenced by genetic factors, but other factors that influence the tendency to become an entrepreneur are influenced by genetics, if all other things are equal, then changes in environmental factors that affect attitudes toward entrepreneurship should have a greater effect on the tendency of people to become entrepreneurs than changes in environmental factors that affect other things. Therefore, our results suggest that the use of entrepreneurship courses to change students' attitudes toward entrepreneurship as a career (Souitaris et al. 2007) is a good focus for entrepreneurship education.

Third, our results bring to the fore the ethical issue of using genetic tests for business purposes. Our results show that science may identify multiple gene systems that allow for more precise predictions about the relationship between genetic factors and the tendency of people to become entrepreneurs. The potential for genetic tests that identify people on the basis of their tendency to become entrepreneurs shows that the ethical problems, which occur when companies collect genetic information on employees, is not limited to current concerns about the potential misuse of data for medical insurance purposes, but can be much broader. Therefore, corporate human resource managers and venture capitalists need to be aware of the new ethical issues that genetics brings to the human resource management process.

Electronic Companion

An electronic companion to this paper is available as part of the online version that can be found at http://mansci.journal.informs.org/.

Acknowledgments

The authors are grateful to Wallace Hopp, the anonymous associate editor, and the anonymous reviewers for their insightful comments and encouragement. They also thank Howard Aldrich, Jaideep Prabhu, and seminar participants at the Massachusetts Institute of Technology, Harvard University, University of Pennsylvania, Case Western Reserve University, Cranfield University, Northwestern University, Imperial College London, Warwick University, the Inaugural Entrepreneurship Conference at London Business School, and a keynote session of the European Doctoral Research Conference for helpful comments on earlier drafts of this paper. The authors are grateful to the twins who participated in the study. The first author thanks the Innovation and Entrepreneurship Group at the Tanaka Business School, Imperial College, London for financial assistance.

References

Ahmed, S. 1985. nAch, risk taking, locus of control and entrepreneurship. *Personality and Individual Differences* **6**(6) 781–782.

Akaike, H. 1987. Factor analysis and AIC. *Psychometrika* **52** 317–332.

Aldrich, H. E., P. Kim. 2007. A life course perspective on occupational inheritance: Self-employed parents and their children. M. Ruef, M. Lounsbury, eds. *Research in the Sociology of Organizations*. Elsevier, Amsterdam, 33–82.

Aldrich, H., G. Wiedenmayer. 1993. From traits to rates: An ecological perspective on organizational foundings. J. Katz, R. Brockhaus, eds. *Advances in Entrepreneurship, Firm Emergence, and Growth*. JAI Press, Greenwich, CT, 145–195.

Aldrich, H., B. Rosen, W. Woodward. 1987. The impact of social networks on business foundings and profit: A longitudinal study. N. Churchill, J. Hornaday, B. Kirchhoff, O. Krasner, K. Vesper, eds. *Frontiers of Entrepreneurship Research*. Babson College, Babson Park, MA, 154–168.

Amit, R., E. Muller, I. Cockburn. 1995. Opportunity costs and entrepreneurial activity. *J. Bus. Venturing* **10**(2) 95–106.

Andrew, T., D. J. Hart, H. Sneider, M. de Lange, T. D. Spector, A. J. MacGregor. 2001. Are twins and singletons comparable? A study of disease-related and lifestyle characteristics in adult women. *Twin Res.* **4** 464–477.

Arvey, R., T. Bouchard, N. Segal, L. Abraham. 1989. Job satisfaction: Environmental and genetic components. *J. Appl. Psych.* **74**(2) 187–192.

Baron, R. A. 2004. The cognitive perspective: A valuable tool for answering entrepreneurship's basic "why" questions. *J. Bus. Venturing* **19**(2) 221–239.

Baron, R., G. Markman. 2003. Beyond social capital: The role of entrepreneurs' social competence in their financial success. *J. Bus. Venturing* **18**(1) 41–60.

Barrick, M. R., M. K. Mount. 1991. The big five personality dimensions and job performance: A meta-analysis. *Personnel Psych.* **44** 1–26.

Bates, T. 1995. Self employment entry across industry groups. *J. Bus. Venturing* **12** 109–124.

Behrman, J. R., P. Taubman. 1989. Is schooling "mostly in the genes?" *J. Political Econom.* **97** 1425–1446.

Benjamin, J., R. P. Ebstein, R. H. Belmaker. 2003. Genes for human personality traits: Endophenotypes of psychiatric disorders? J. Benjamin, R. P. Ebstein, R. H. Belmaker, eds. *Molecular Genetics and the Human Personality*. American Psychological Association, Washington, D.C., 333–343.

Benjamin, J., L. Li, C. Patterson, B. D. Greenburg, D. L. Murphy, D. H. Hamer. 1996. Population and familial association between the D4 dopamine receptor gene and measures of novelty seeking. *Nature Genetics* **12** 81–84.

Berridge, K. C., T. E. Robinson. 1998. What is the role of dopamine in reward: Hedonic impact, reward learning, or incentive salience? *Brain Res. Rev.* **28**(3) 309–369.

Betsworth, D., T. Bouchard, C. Cooper, H. Grotevant, J. Hansen, S. Scarr, R. Weinberg. 1994. Genetic and environmental influences on vocational interests assessed using adoptive and biological families and twins reared together and apart. *J. Vocational Behav.* **44** 263–278.

Bitler, M. P., T. Moskowitz, A. Vissing-Jørgensen. 2005. Testing agency theory with entrepreneur effort and wealth. *J. Finance* **60**(2) 539–576.

Bouchard, T. 1998. Genetic and environmental influences on intelligence and special mental abilities. *Human Biology* **70**(2) 257–259.

Bouchard, T., J. Propping. 1993. *Twins as a Tool of Behavioral Genetics*. John Wiley & Sons, Chichester, UK.

Bouchard, T., D. Lykken, N. McGue, N. Segal, A. Tellegen. 1990. Sources of human psychological difference: The Minnesota study of twins reared apart. *Science* **12**(October) 223–228.

Bouchard, T. J., Jr., J. C. Loehlin. 2001. Genes, evolution and personality. *Behav. Genetics* **31** 243–273.

Bouchard, T. J., Jr., N. L. Segal, A. Tellegen, M. McGue, M. Keyes, R. Krueger. 2004. Genetic influence on social attitudes: Another challenge to psychology from behavioural genetics. L. F. DiLalla, ed. *Behavior Genetics Principles: Perspectives in Development, Personality, and Psychopathology*. American Psychological Association, Washington, D.C., 89–104.

Browne, M. W. 1982. Covariance structures. D. M. Hawkins, ed. *Topics in Applied Multivariate Analysis*. Cambridge University Press, Cambridge, UK, 72–141.

Browne, M. W. 1984. Asymptotically distribution-free methods for the analysis of covariance structures. *British J. Math. Statist. Psych.* **37** 62–83.

Bulik, C. M., P. F. Sullivan, T. D. Wade, K. S. Kendler. 2000. Twin studies of eating disorders. *Internat. J. Eating Disorders* **27**(1) 1–20.

Burke, A. E., F. R. FitzRoy, M. A. Nolan. 2000. When less is more: Distinguishing between entrepreneurial choice and performance. *Oxford Bull. Econom. Statist.* **62** 567–587.

Busenitz, L. 1999. Entrepreneurial risk and strategic decision making. *J. Appl. Behav. Sci.* **35**(3) 325–340.

Carey, G. 2003. *Human Genetics for the Social Sciences*. Sage Publications, Thousand Oaks, CA.

Cherny, S. S., J. C. DeFries, D. W. Fulker. 1992. Multiple regression of twin data: A model-fitting approach. *Behav. Genetics* **22** 489–497.

Clouse, V. 1990. A controlled experiment relating entrepreneurial education to students' start-up decisions. *J. Small Bus. Management* **28** 45–53.

Comings, D., R. J. Rosenthal, H. R. Lesieur, L. J. Rugle, D. Muhleman, C. Chiu, G. Dietz, R. Gade. 1996. A study of the dopamine receptor gene in pathological gambling. *Pharmacogenetics* **6**(3) 223–234.

Cooper, A., C. Woo, W. Dunkelberg. 1988. Entrepreneurs' perceived chances for success. *J. Bus. Venturing* **3**(2) 97–108.

Cropanzano, R., K. James. 1990. Some methodological considerations for the behavioral genetic analysis of work attitudes. *J. Appl. Psych.* **75**(4) 433–439.

Cyphers, L. H., K. Phillips, D. W. Fulker, D. A. Mrazek. 1990. Twin temperament during the transition from infancy to early childhood. *J. Am. Acad. Child Adolesc. Psychiatry* **29** 392–397.

Delmar, F., P. Davidsson. 2000. Where do they come from? Prevalence and characteristics of nascent entrepreneurs. *Entrepreneurship Regional Development* **12** 1–23.

Delmar, F., S. Shane. 2003. Does business planning facilitate the development of new ventures? *Strategic Management J.* **24**(12) 1165–1185.

De Wit, G., F. A. A. M. van Widen. 1989. An empirical analysis of self employment in the Netherlands. *Small Bus. Econom.* **1** 263–272.

Eaves, L. J., H. J. Eysenck, N. G. Martin. 1989. *Genes, Culture and Personality: An Empirical Approach.* Academic Press, New York.

Ebstein, R. P., O. Novick, R. Umansky, B. Priel, Y. Osher, D. Blaine. 1996. Dopamine D_4 receptor (D_4DR) exon III polymorphism associated with the human personality trait novelty-seeking. *Nature Genetics* **12** 78–80.

Evans, D., L. Leighton. 1989. Some empirical aspects of entrepreneurship. *Amer. Econom. Rev.* **79** 519–535.

Fairlie, R. 1999. The absence of African-American owned businesses: An analysis of the dynamics of self-employment. *J. Labor Econom.* **17**(1) 80–108.

Falconer, D. 1989. *Introduction to Quantitative Genetics*. Longman Group, Harlow, Essex, UK.

Gaglio, C. M., J. A. Katz. 2001. The psychological basis of opportunity identification: Entrepreneurial alertness. *Small Bus. Econom.* **16**(2) 95–111.

Gartner, W. 1988. Who is an entrepreneur? Is the wrong question. *Amer. J. Small Bus.* **12**(4) 11–32.

Gartner, W., N. Carter. 2003. Entrepreneurial behaviour and firm organizing proceses. Z. Acs, D. Audretsch, eds. *Handbook of Entrepreneurship Research*. Kluwer, Boston, 195–222.

Gottfredson, L. S. 1999. The nature and nurture of vocational interests. M. L. Savickas, A. R. Spokane, eds. *Vocational Interests: Their Meaning, Measurement, and Use in Counseling*. Davies-Black, Palo Alto, CA, 57–85.

Hakim, A. J., L. F. Cherkas, R. Grahame, T. D. Spector, A. J. MacGregor. 2004. The genetic epidemiology of joint hypermobility: A population study of female twins. *Arthritis & Rheumatism* **50**(8) 2640–2644.

Hettema, J. M., M. C. Neale, K. S. Kendler. 1995. Physical similarity and the equal environment assumption in twin studies of psychiatric disorders. *Behav. Genetics* **25** 327–335.

Hull, D., J. Bosley, G. Udell. 1980. Renewing the hunt for the Heffalump: Identifying potential entrepreneurs by personality characteristics. *J. Small Bus. Management* **18** 11–18.

Jang, K. L., W. J. Livesley, P. A. Vernon. 1996. Heritability of the big five personality dimensions and their facets: A twin study. *J. Personality* **64** 577–591.

Joreskog, K. 1990. New developments in Lisrel: Analysis of ordinal variables using polychoric correlations and weighted least squares. *Quality Quantity* **24** 387–404.

Keller, L., T. Bouchard, R. Arvey, N. Segal, R. Dawes. 1992. Work values: Genetic and environmental influences. *J. Appl. Psych.* **77**(1) 79–88.

Kendler, K. S., L. J. Eaves. 1986. Models for the joint effects of genotype and environment on liability to psychiatric illness. *Amer. J. Psychiatry* **143** 279–289.

Kendler, K. S., L. M. Thornton, N. L. Pedersen. 2000. Tobacco consumption in Swedish twins reared together and reared apart. *Arch. General Psychiatry* **57** 886–892.

Kendler, K. S., M. C. Neale, R. C. Kessler, A. C. Heath, L. J. Eaves. 1993. A test of the equal environment assumption in twin studies of psychiatric illness. *Behav. Genetics* **23** 21–27.

Kolvereid, L. 1996. Organisational employment versus self employment: Reasons for career choice intentions. *Entrepreneurship Theory Practice* **20**(3) 23–31.

Krueger, N. 1993. Growing up entrepreneurial. *Acad. Management Proc., Atlanta, GA*.

Lichtenstein, P., N. L. Pedersen, G. E. McClearn. 1992. Genetic and environmental predictors of socioeconomic status. *Behav. Genetics* **22** 731–732.

Luthje, C., N. Franke. 2003. The "making" of an entrepreneur: Testing a model of entrepreneurial intent among engineering students at MIT. *R&D Management* **33**(2) 135–147.

Lykken, D., T. Bouchard, M. McGue, A. Tellegen. 1993. Heritability of interests: A twin study. *J. Appl. Psych.* **78**(4) 649–661.

MacGregor, A. 2000. Practical approaches to account for bias and confounding in twin data. T. Spector, H. Sneider, A. MacGregor, eds. *Advances in Twin and Sib-Pair Analysis*. Greenwich Medical Media, London, 35–52.

Martin, N. G., L. J. Eaves. 1977. The genetic analysis of covariance structure. *Heredity* **38**(1) 79–95.

Martin, N. G., P. G. Martin. 1975. The inheritance of scholastic abilities in a sample of twins: Ascertainment of the sample and diagnosis of zygosity. *Ann. Human Genetics* **39** 213–218.

McClelland, D. 1961. *The Achieving Society*. Van Nostrand, Princeton, NJ.

McGue, M., T. Bouchard. 1984. Adjustment of twin data for the effects of age and sex. *Behav. Genetics* **14** 325–343.

McGue, M., T. J. Bouchard Jr. 1998. Genetic and environmental influences on human behavioral differences. *Annual Rev. Neuroscience* **21** 1–24.

McGue, M., R. Wette, D. Rao. 1987. A Monte Carlo evaluation of three statistical methods used in path analysis. *Genetic Epidemiology* **429** 129–155.

Mesch, G. S., D. Czamanski. 1997. Occupational closure and immigrant entrepreneurship: Russian Jews in Israel. *J. Socio-Economics* **26**(6) 597–610.

Moffitt, T. E., A. Caspi, M. Rutter. 2005. Strategy for investigating interactions between measured genes and measured environments. *Arch. General Psychiatry* **62** 473–481.

Mohammed, I., L. F. Cherkas, S. A. Riley, T. D. Spector, N. J. Trudgill. 2003. Genetic influences in gastro-oesophageas reflux disease: A twin study. *Gut* **52** 1085–1089.

Moloney, D. P., T. J. Bouchard, N. L. Segal. 1991. A genetic and environmental analysis of the vocational interests of monozygotic and dizygotic twins reared apart. *J. Vocational Behav.* **39**(1) 76–109.

Neale, M. C. 2004. *Mx Software*. Department of Psychiatry, Virginia Commonwealth University, Richmond, VA.

Neale, M. C., H. H. M. Maes. 2002. *Methodology for Genetic Studies of Twins and Families*. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Neale, M. C., L. R. Cardon. 1992. *Methodology for Genetic Studies of Twins and Families*. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Parker, S. C. 2004. *The Economics of Self-Employment and Entrepreneurship*. Cambridge University Press, Cambridge, UK.

Pearlman, E. M., J. A. Ganon. 2000. *Raising Twins: What Parents Want to Know, and What Twins Want to Tell Them*. Harper Resource, New York.

Peeters, H., S. Gestel, R. Vlietinck, C. Derom, R. Derom. 1998. Validation of a telephone zygosity questionnaire in twins of known zygosity. *Behav. Genetics* **28**(3) 159–163.

Plomin, R., D. Daniels. 1987. Why are children in the same family so different from one another? *Behav. Brain Sci.* **10**(1) 1–16.

Plomin, R., F. M. Spinath. 2004. Intelligence: Genetics, genes, and genomics. *J. Personality Social Psych.* **86** 112–129.

Plomin, R., S. O. Walker. 2003. Genetics and educational psychology. *British J. Educational Psych.* **73** 3–14.

Plomin, R., J. C. DeFries, J. C. Loehlin. 1977. Genotype-environment interaction and correlation in the analysis of human behavior. *Psych. Bull.* **84** 309–322.

Plomin, R., J. C. DeFries, G. E. McClearn. 1990. *Behavioral Genetics: A Primer*, 2nd ed. Freeman, New York.

Plomin R., J. C. DeFries, G. E. McClearn, P. McGuffin. 2001. *Behavioral Genetics*, 4th ed. Worth Publishers, New York.

Plomin, R., P. Lichtenstein, N. L. Pedersen, G. E. McClearne, J. R. Nesselroade. 1990. Genetic influence on life events during the last half of the life span. *Psych. Aging* **5** 25–30.

Reynolds, P., N. Carter, W. Gartner, P. Greene. 2004. The prevalence of nascent entrepreneurs in the United States: Evidence from the panel study of entrepreneurial dynamics. *Small Bus. Econom.* **23** 263–284.

Riemann, R., A. Angleitner, J. Strelau. 1997. Genetic and environmental influences on personality: A study of twins reared together using the self- and peer report NEO-FFI scales. *J. Personality* **65** 449–475.

Ritsila, J., H. Tervo. 2002. Effects of unemployment on new firm formation: Micro-level panel data evidence from Finland. *Small Bus. Econom.* **19** 31–40.

Rowe, D. C. 1994. *The Limits of Family Influence*. Guilford Press, New York.

Rowe, D. C. 2003. Assessing genotype X environment interactions and correlations in a postgenomic world. R. Plomin, J. C. DeFries, I. W. Craig, P. McGuffin, eds. *Behavioral Genetics in the Postgenomic Era*. American Psychological Association, Washington, D.C., 71–99.

Ruef, M., H. Aldrich, N. Carter. 2003. The structure of founding teams: Homophily, strong ties, and isolation among U.S. entrepreneurs. *Amer. Sociol. Rev.* **68** 195–222.

Scarr, S. 1992. Developmental theories for 1990s: Development and individual differences. *Child Development* **63** 1–19.

Scarr, S., L. Carter-Saltzman. 1979. Twin method: Defense of a critical assumption. *Behav. Genetics* **9** 527–542.

Segal, N. 1999a. *Entwined Lives: Twins and What They Tell Us About Human Behavior*. Dutton, New York.

Segal, N. 1999b. New twin studies show ... the career of your dreams may be the career of your genes. *Psych. Today* **32**(Sept.–Oct.) 54–70.

Segal, N. 2005. *Indivisible by Two: Lives of Extraordinary Twins*. Harvard University Press, Cambridge, MA.

Sham, P. 1998. *Statistics in Human Genetics*. Arnold, London, UK.

Sham, P. C., E. E. Walters, M. C. Neale, A. C. Heath, C. J. MacLean, K. S. Kendler. 1994. Logistic regression analysis of twin data: Estimation of parameters of the multifactorial liability-threshold model. *Behav. Genetics* **24** 229–238.

Shane, S. 2000. Prior knowledge and the discovery of entrepreneurial opportunities. *Organ. Sci.* **11** 448–469.

Shane, S. 2003. *A General Theory of Entrepreneurship: The Individual-Opportunity Nexus*. Edward Elgar Publishing, Aldershot, UK.

Shane, S., S. Venkataraman. 2000. The promise of entrepreneurship as a field of research. *Acad. Management Rev.* **25** 217–226.

Singer, J. J., A. J. MacGregor, L. F. Cherkas, T. D. Spector. 2005. Where did I leave my keys? A twin study of self-reported memory ratings using the multifactorial memory questionnaire. *Twin Res. Human Genetics* **8**(2) 108–112.

Sorenson, J. 2007. Closure versus exposure: Mechanisms in the intergenerational transition of self-employment. M. Ruef, M. Lounsbury, eds. *Research in the Sociology of Organizations*. Elsevier, Amsterdam, 83–124.

Souitaris, V., S. Zerbinati, A. Al-Laham. 2007. Do entrepreneurship programmes raise entrepreneurial intention of science and engineering students? The effect of learning, inspiration and resources. *J. Bus. Venturing* **22**(4) 566–591.

Spector, T., F. Cicuttini, J. Baker, J. Loughlin, D. Hart. 1996. Genetic influences on osteoarthritis in women: A twin study. *British Medical J.* **312** 940–944.

Stewart, W., P. Roth. 2001. Risk taking propensity differences between entrepreneurs and managers: A meta-analytic review. *J. Appl. Psych.* **86**(1) 145–153.

Tambs, K., J. M. Sundet, P. Magnus, K. Berg. 1989. Genetic and environmental contributions to the covariance between occupational status, educational attainment and IQ: A study of twins. *Behav. Genetics* **19** 209–222.

Taubman, P. 1976. The determinants of earnings: Genetics, family, and other environments; A study of white male twins. *Amer. Econom. Rev.* **66** 858–870.

Taylor, M. 1996. Earnings, independence or unemployment: Why become self-employed? *Oxford Bull. Econom. Statist.* **58**(2) 253–266.

Thornton, P., K. Flynn. 2003. Entrepreneurship, networks and geographies. Z. Acs, D. Audretsch, eds. *Handbook of Entrepreneurship Research*. Kluwer, Boston, 401–436.

Turkheimer, E., B. M. D'Onofrio, H. H. Maes, L. J. Eaves. 2005. Analysis and interpretation of twin studies with measured environments. *Child Development* **76**(6) 1217–1233.

Uusitalo, R. 2001. "Homo entreprenaurus?" *Appl. Econom.* **33** 1631–1638.

Van Praag, C., J. Cramer. 2001. The roots of entrepreneurship and labour demand: Individual ability and low aversion. *Economica* **68**(269) 45–62.

Volkow, N. D. 2004. Mediation of saliency in health and addiction. *157th Annual Meeting of the American Psychiatric Association, New York*.

White, R., S. Thornhill, E. Hampson. 2006. Entrepreneurs and evolutionary biology: The relationship between testosterone and new venture creation. *Organ. Behav. Human Decision Processes* **100** 21–34.

White, R., S. Thornhill, E. Hampson. 2007. A biosocial model of entrepreneurship: The combined effects of nurture and nature. *J. Organ. Behav.* **28** 451–466.