

The Heritability of Attitude Toward Economic Risk

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The propensity to take risk underpins a wide variety of decision-making behavior, ranging from common ones such as asking for directions and trying out a new restaurant to more substantial economic decisions involving, for instance, one's investment or career. Despite the fundamental role of risk attitude in the economy, its genetic basis remains unknown. Using an experimental economics protocol combined with a classical twin strategy, we provide the first direct evidence of the heritability of economic risk attitude, at 57%. We do not find a significant role for shared environmental effects, a common observation in behavioral genetics that is contrary to commonly held views in economics. Our findings complement recent neuroeconomic studies in enhancing the understanding of the neurobiological basis of risk taking.

Keywords: economic risk, behaviour genetics, experimental economics

Risks figure prominently in decision-making today, from trying out a new restaurant to investing in the stock market, as well as in the distant past, when exposure to the elements was commonplace. From then to now, a willingness to take risk remains essential to the human condition. It is therefore not surprising that risk has been the focus of much research in economics (Chew, 1983; Chew et al., 1991; Kahneman & Tversky, 1979; Quiggin, 1982; Savage, 1954; von Neumann & Morgenstern, 1944). Recently, risk-taking has been explored from a neurobiological perspective (Hsu et al., 2005; Smith et al., 2002; Tom et al., 2007). Despite its fundamental importance in economics, the genetic basis of human variation in risk attitude remains obscure. Should such variability be due to genetic factors, linkage and association studies could be performed to identify genes that associate with attitudes to risk. Understanding the neurobiological basis of attitude to risk could help economists test and formulate better models of indi-

vidual decision-making, and ultimately improve the design of economic mechanisms and the formulation of public policies.

To examine the genetic contributions to risk attitude in humans, we employ a classical twin design with MZ twins who have essentially the same DNA, and DZ twins, who on average share half of their DNA (Bouchard & McGue, 2003; Turkheimer, 2000). Under the hypothesis of an equally shared environment, we are able to test for genetic effects and subsequently decompose the overall variance in risk attitude into the variance due to genetic factors and the variance due to environmental factors by comparing the correlation in risk attitude between MZ twins and the corresponding correlation between DZ twins.

Materials and Methods

We recruited 167 MZ same-sex twin pairs and 65 DZ twin pairs (115 male pairs, 117 female pairs; mean age = 30.8 ± 15.1 years [SD], from 15 to 69 years old) from Fujian, Beijing, Wuhan and Hefei, from May 2007 to April 2008. Both twins were required to attend the same experimental session. Zygosity was determined by questionnaire, which yields correct classifications more than 95% of the time (Cederlof et al., 1961; Cohen et al., 1975). In the presence of an experimental monitor, subjects are presented with three alternatives: receiving 15 Yuan for sure, receiving 20 Yuan for sure, and receiving a lottery paying 40 Yuan or zero with equal probability (a student's typical hourly wage is 10 Yuan in China, which is about US\$1.40). Subjects first indicate their best alternative among the three and subsequently indicated their preferred choice among the remaining two alter-

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natives. Subjects received their first best alternative as payment. The English translation of the instructions is as follows:

Here are 20 cards with 10 red and 10 black. We will randomly draw a card, and you can decide whether you would like to guess at the color of the card. If you guess it correctly, you will get 40 Yuan, otherwise you will get 0. If you don't guess, you will get a certain amount of money.

You will have the following options: (1) Guess (2) 20 Yuan (3) 15 Yuan;

1. Please tick your favorite option, and you will be paid based on your choice.
 - (1) Take a guess, bet on red ___ black ___
 - (2) 20 Yuan
 - (3) 15 Yuan
2. Beside your favorite option, please tick the one you like more.
 - (1) Take a guess, bet on red ___ black ___
 - (2) 20 Yuan
 - (3) 15 Yuan.

Based on their decision, subjects' risk attitudes are coded as follows: H (high) if choosing the lottery is the first best choice; M (medium) if choosing the lottery is the second best choice; L (low) if choosing the lottery is the worst choice. There were 12 observations we could not categorize — nine stated a preference for 15 Yuan over 20 Yuan, and three identified the 20 Yuan alternative as both their first best as well as their second best. Data from these individuals and their siblings were discarded from our sample, leaving responses from 220 complete pairs (158 MZ, 62 DZ; 109 male pairs, 111 female pairs; mean age = 30.00 ± 14.63 years [SD]).

Results

Based on subjects' choices, three levels of risk attitude were observed, 70% of high risk taking (H), 12% of medium risk taking (M) and 18% of low risk taking

(L). The distributions of responses for MZ and DZ twins as well as male and female subjects do not differ significantly (by zygosity, $\chi^2 = 0.86, p < .65$; by sex, $\chi^2 = 1.93, p < .38$).

We obtained maximum likelihood estimates for the polychoric correlations of the contingency tables (Figure 1) using Mx (Neale & Cardon, 1992). After adjusting for the effects of age and sex, the polychoric correlation is 0.57 (95% CI = 0.36, 0.74) for MZ twin pairs, and 0.02 (95% CI = -0.34, 0.39) for DZ twin pairs. The difference is statistically significant ($\chi^2 = 6.84, p < .009$). The large difference for correlations of MZ pairs and DZ pairs suggests strong genetic effects on variation in risk attitude.

We further estimated the relative contributions of additive (A) and nonadditive (D) genetic effects, and shared (C) and nonshared (E) environmental effects to total variance, under the standard ACE and ADE models and their submodels (Neale & Cardon, 1992; Table 1). After adjusting for the effects of age and sex, the CE model and E model are both rejected (CE model, $\chi^2 = 5.02, p < .025$; E model, $\chi^2 = 20.75, p < .001$). This again suggests significant genetic effects. Point estimates of broad heritability (A + D) are greater than 50% for all model specifications incorporating A or D. For ACE model, the estimated shared environmental effects is 0% (95% CI = 0%, 37.0%). For ADE model, the point estimate of D for ADE model is 56.6% (95% CI = 0.0%, 73.1%), while A is estimated at 0% (95% CI = 0.0%, 67.9%). This suggests large nonadditive genetic effects relative to additive genetic effects.

Discussion

Our finding that genetic factors account for 57% of the variation in the risk attitude of normal subjects is the first such finding with a Chinese population. An independent study using the Swedish twin registry finds heritability of risk attitude at 14% (95% CI = 2%, 27%; Cesarini et al., in press). Intriguingly, recent neuroeconomics studies using a similar lottery design have found neural correlates for risk attitude in regions of the prefrontal cortex (Hsu et al., 2005; Tom

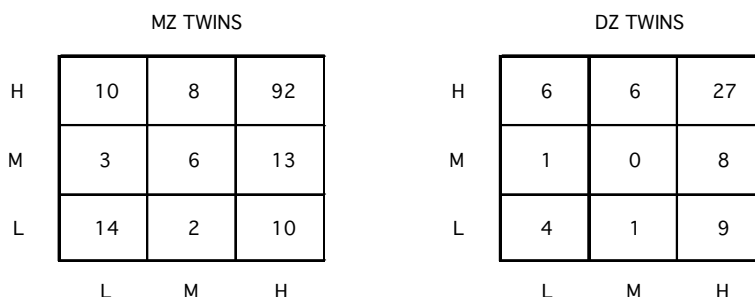


Figure 1
Contingency tables for MZ and DZ twins — H represents high risk taking; M represents modest risk taking; L represents risk averse.

Table 1
Goodness-of-Fit Statistics and Estimates for ACE and ADE Models

Model	df	χ^2	P	AIC	A	D	C	E
Adjusted ACE	433	681.56	—	-184.44	53.91% (9.52%–71.06%)	—	0.00% (0.00%–37.00%)	46.09% (28.94%–67.75%)
ACE/Drop Age	435	691.52	0.007	-178.48	56.98% (12.57%–73.16%)	—	0.00% (0.00%–37.51%)	43.02% (26.84%–63.77%)
ACE/Drop Sex	436	691.68	0.018	-180.32	57.11% (13.10%–73.23%)	—	0.00% (0.00%–37.19%)	42.89% (26.77%–63.59%)
ACE/Drop A	434	686.57	0.025	-181.43	—	—	41.45% (21.62%–58.56%)	58.55% (41.44%–78.37%)
ACE/Drop C	434	681.56	1	-186.44	53.91% (32.25%–71.06%)	—	—	46.09% (28.94%–67.75%)
ACE/Drop AC	435	702.31	0	-167.69	—	—	—	100%
Adjusted ADE	433	680.13	—	-185.87	0.00% (0.00%–69.90%)	56.64% (0.00%–73.05%)	—	43.36% (26.95%–64.85%)
ACE/Drop	435	690.17	0.007	-179.83	0.00% (0.00%–70.40%)	59.43% (0.00%–74.88%)	—	40.57% (25.12%–61.08%)
ACE/Drop	436	690.29	0.017	-181.71	0.00% (0.00%–70.40%)	59.54% (0.00%–74.95%)	—	40.46% (25.05%–60.89%)

et al., 2007), the size of which was also shown to be heritable (Thompson et al., 2001). These results suggest that the genetic component of risk observed in the current study may be mediated by individual neurochemical and neuroanatomical differences in the prefrontal cortex.

An individual's risk attitude can vary from being risk averse to being risk preferring. When observed through the methodology of experimental economics, risk attitude may gainfully be considered a personality trait, which appears to be distinct from novelty seeking in Tridimensional Personality Questionnaire (Cloninger, 1987), extraversion in the Big Five Personality (Costa & McCrae, 1992) or sensation seeking (Zuckerman, 2004) traits. Risk attitude seems to be a stable personality trait, since life time experience does not seem to have a significant impact on behavioral patterns (Dror et al., 1998; Kovalchik et al., 2005).

As an integral part of daily living, economic risk taking is distinct from 'risky behavior', such as smoking, unprotected sex, driving while under the influence, and in extreme cases drug abuse and pathological gambling, which can endanger the individual with no apparent economic benefit. While little is known regarding the genetics of risk attitude in economics, there is a considerable literature on the genetics of 'risky' behaviors; for example, several twin studies demonstrate a significant heritable component in pathological gambling (Shah et al., 2005). The current investigation, in which risk-taking behavior of nonclinical subjects is observed using a laboratory-based economic paradigm involving lotteries with well-defined probabilities and actual money outcomes, is distinct from twin studies of pathological gambling that tend to be based on *Diagnostic and Statistical Manual of Mental Disorders* (American Psychiatric Association, 2000) clinical nosology.

Numerous studies have documented a strong correlation in the economic outcomes between parents and their children, including educational attainment (Black et al., 2005), occupation (Kerckhoff et al., 1985), income (Mulligan, 1997), and wealth (Charles & Hurst, 2003). For the latter, several determinants have been proposed, including human resource investment, bequest motive, the heritability of IQ, and the heritability of risk attitude. The present article provides the first substantive evidence of the heritability of risk attitude as a part of the mechanism for the intergenerational transmission of economic wealth. Because children inherit similar attitude to risk and thus make similar decisions involving risk as their parents, such as investment decisions, they may end up with similar outcomes. Our finding of the heritability of risk attitude has direct implications for societal policy on income and wealth redistribution through income tax and inheritance tax. Moreover, should the correlation in educational outcomes across generations partly reflect heritability of risk attitude, policy intended to

change this persistence would need to go beyond changing the financial or educational endowment of parents. Future work involving gene and environment interaction, especially from a developmental perspective (Heckman, 2007), would be critical to understanding the formation of risk preference and have sharper policy implications on societal issues including income inequality and economic growth.

A recent study of risk attitude in our evolutionary past (Chen et al., 2006) shows that the behavior of Capuchin monkeys displays patterns of decision-making under risk akin to those of humans, suggesting that the roots of human risk attitude have antecedents in our primate past. We also find strong nonadditive genetic effect relative to additive genetic effects in ADE model, strengthening the notion that the trait — risk attitude — has been under natural selection, including mutation selection and balancing selection (Falconer, 1996). Over the course of primate evolution it appears, therefore, that risk attitude has been preserved as an important behavioral mechanism for survival. Indeed, there is a growing literature on evolutionary models of risk-taking in economics (Dekel & Scotchmer, 1999; Karni & Schmeidler, 1986; Robson, 1996; Wärneryd, 2002). Specifically, our finding supports the equilibrium outcome in Wärneryd's model (Wärneryd, 2002), involving multiple genotypes being selected, over those models with single-genotype equilibria.

Having established the heritability of risk attitude using a classical twin approach in conjunction with an economic game, the stage is set for the identification of specific gene polymorphisms underlying this phenotype. Studying economic decision-making — individual as well as social (Cesarini et al., 2008b; Knafo et al., 2008; Wallace et al., 2007) — from the perspective of genetics appears to be a promising direction for further research. This article marks the first time the methodology of behavioral genetics is introduced to understand individual choice behavior, thereby contributing to an emerging literature incorporating neurobiological considerations in the modeling and analysis of economic behavior.

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