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Nature or nurture: What determines investor behavior? ☆

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ABSTRACT

Using data on identical and fraternal twins' complete financial portfolios, we decompose the cross-sectional variation in investor behavior. We find that a genetic factor explains about one-third of the variance in stock market participation and asset allocation. Family environment has an effect on the behavior of young individuals, but this effect is not long-lasting and disappears as an individual gains experience. Frequent contact among twins results in similar investment behavior beyond a genetic factor. Twins who grew up in different environments still display similar investment behavior. Our interpretation of a genetic component of the decision to invest in the stock market is that there are innate differences in factors affecting effective stock market participation costs. We attribute the genetic component of asset allocation—the relative amount invested in equities and the portfolio volatility—to genetic variation in risk preferences.

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1. Introduction

It is a well-documented empirical fact in the finance literature that there is significant heterogeneity across individuals in investment behaviors such as the decision to invest in the stock market and the choice of asset allocation.[1] Are individual investors genetically predisposed to certain behaviors and born with a persistent set of abilities and preferences which affect their decisions in the financial domain?[2] Or is investment behavior to a significant extent shaped by environmental factors, such as parenting or individual-specific experiences? These questions are fundamental for our understanding of the behavior of individual investors, but so far existing research has not offered much systematic evidence on them. In this paper, we seek to fill this void by estimating the extent to which "nature," i.e., genetic variation across individuals, versus "nurture" or other environmental treatments, explain the observed heterogeneity in investment decisions.

To decompose the variance of three important measures of investment behavior—stock market participation, the relative amount invested in equities (share of equities), and portfolio volatility—into genetic and environmental components, we examine identical and fraternal twins. The intuition of our identification strategy is straightforward: if individuals who are more closely related genetically (e.g., identical twins) tend to be more similar on measures of investment behavior, then this is evidence for that behavior being, at least partially, caused by a genetic factor. Using data on twins allows us to identify an unobservable genetic component and environmental components that are either common (shared) or non-shared among twins.

Our data on 37,504 twins are from the Swedish Twin Registry, which maintains and manages the world's largest database of twins. Until the abolishment of the wealth tax in Sweden in 2006, the law required all financial institutions to report information to the Swedish Tax Agency about the assets an individual owned as of December 31 of that year. This allows us to compile a matched data set of twins and their complete financial portfolios.

Our empirical evidence shows that about a third of the cross-sectional variation in stock market participation and asset allocation decisions across individuals is explained by a genetic factor. We also demonstrate that the genetic component does not disappear with age, is significant even among twins who do not interact frequently, and accounts for a significant proportion of the variance also among pairs of twins who were reared apart. While our evidence implies that nature is an important determinant of an individual's investment behavior, we also show considerable environmental influences. Our evidence indicates that environmental influences that contribute to variation in investor behavior are those that make family members different, not similar. That is, the non-shared environment tends to be much more important than the shared environment in explaining differences in investment behaviors. The family environment has a significant effect on the investment behavior of young individuals, but this effect is not long-lasting (unless the twins stay in frequent contact) as we find that it disappears when an individual gains experiences relevant for decisions in the investment domain.

In a standard frictionless model of asset allocation, all individuals, no matter how risk averse they are, should invest at least a fraction of their portfolio in equities. But participation costs can cause non-participation among some individuals.[3] As a result, our interpretation of a significant genetic component of the decision to invest in the stock market is that there are individual-specific innate differences in factors that affect the magnitude of effective stock market participation costs.

Controlling for wealth, educational achievement, and several background risk factors does not change our finding. This suggests that additional, heritable characteristics (unobservable to us) play an important role in explaining stock market participation. This is consistent with evidence in finance that risk aversion, social interactions, trust, and most recently cognitive ability and even height are associated with stock market participation. Long-standing research in behavioral genetics has found that these characteristics have a significant genetic component. Our evidence thus suggests that accounting for genetic variation should be helpful in understanding these findings better.

Our paper also contributes to research on the determinants of variation in asset allocation (share in equity and portfolio volatility) across individuals. Standard models show that in a frictionless market, differences in risk preferences and possibly in wealth (if risk aversion is a function of wealth) are the main sources of cross-sectional variation in the share in equities, (e.g., Samuelson, 1969; Merton, 1969). Recently, financial economists have also examined the influence of life-cycle effects (Ameriks and Zeldes, 2004) and various background risk factors which are absent in a standard model (e.g., Heaton and Lucas, 2000; Rosen and Wu, 2004; Love, 2010). However, the explanatory power with respect to asset allocation of such observable factors is low. For example, the adjusted R^2 is only 2–3% in most asset allocation studies (for a recent example, see Brunnermeier and Nagel, 2008). Our evidence demonstrates that modeling a genetic component significantly improves our ability to explain the variation in asset allocation across individuals. Importantly, because we control for

[1] See, e.g., Campbell (2006) and Curcuru, Heaton, Lucas, and Moore (2009) for recent and extensive reviews of the emerging field of "household finance" and, specifically, research on the cross-sectional variance in investment behavior.

[2] There is a long-standing view in economics that preferences are at least partly genetic (e.g., Robson, 2001a), and Robson (2001b, p. 201), goes as far as stating that "[i]f preferences are significantly shaped by individual experiences, the changes needed in economic theory are profound." For early work in economics from a biological viewpoint, see Hirshleifer (1977).

[3] Vissing-Jørgensen (2002b) shows that relatively small ongoing participation costs can explain the non-participation rate in the stock market.

wealth as well as background risk factors commonly studied in the literature, such as entrepreneurial activity, health status, and marital status, our interpretation of the evidence is that genetic variation in risk preferences explains the genetic component of individuals' asset allocation decisions. Such an interpretation is consistent with recent experimental evidence on genetically determined preferences for risk-taking (e.g., Kuhnen and Chiao, 2009; Cesarini, Dawes, Johannesson, Lichtenstein, and Wallace, 2009a).

The paper is organized as follows. Section 2 contains an overview of related research. Section 3 describes the empirical research methodology we use to quantitatively decompose the variance in investment behavior into genetic and environmental components. Section 4 describes our data on twins and their investment portfolio, and defines the variables of interest. Section 5 reports our results and robustness checks, and Section 6 contains further evidence and extensions. Section 7 discusses our evidence and implications, and Section 8 concludes.

2. Overview of related research

The question of the relative importance of nature versus nurture in explaining investment behavior is related to an extensive body of work in behavioral genetics and to recent studies in economics and finance. In this section, we provide an overview of the results that have emerged so far from these literatures.

2.1. Genetics and preferences for risk-taking

Two recent twin studies which estimate the genetic component of individuals' risk-taking preferences are Cesarini, Dawes, Johannesson, Lichtenstein, and Wallace (2009a) and Zyphur, Narayanan, Arvey, and Alexander (2009). Using experiments involving lottery choices and questionnaires, they elicit subjects' risk preferences and then use twin research methodology to estimate genetic effects. They find evidence of a significant genetic component which partly explains the heterogeneity in risk preferences. However, eliciting preferences for risk-taking using experiments is problematic and may not necessarily provide a reliable measure (Harrison, List, and Towe, 2007).[4] Both studies also employ small samples that are subject to potential sample selection bias. For example, in Cesarini, Dawes, Johannesson, Lichtenstein, and Wallace (2009a), 80% of the subjects are female twins who were selected to participate in an experiment session (both twins in a pair had to be able to attend the session), and Zyphur, Narayanan, Arvey, and Alexander (2009) study only male twins. Our paper does not use an experimental approach, but studies real investment behavior as revealed by individuals' portfolio choices.

Our work is most closely related to an independent study of Swedish twins by Cesarini, Johannesson, Lichtenstein, Sandewall, and Wallace (forthcoming). However, the analysis and the data sets are different. First, we examine individuals' overall financial portfolios, while Cesarini, Johannesson, Lichtenstein, Sandewall, and Wallace (forthcoming) study a subset of an individual's portfolio: the public retirement savings account created in the pension reform in Sweden in 2000. In these accounts, individuals allocate 2.5%, up to a cap, of their annual labor income. The initial retirement savings accounts were small, and individuals may not have devoted significant effort to choose optimal portfolios, but were influenced by advertising by fund managers and the government (Cronqvist and Thaler, 2004). While Cesarini, Johannesson, Lichtenstein, Sandewall, and Wallace (forthcoming) do not provide summary statistics for the value of these accounts, we estimate they represent approximately 5% of investors' total financial wealth. Second, we study standard measures in financial economics, in particular stock market participation and the share of financial assets invested in equities, while Cesarini, Johannesson, Lichtenstein, Sandewall, and Wallace (forthcoming) focus on return volatility.[5] Finally, the investment opportunity sets available to investors are different. In our data set, individuals have access to all direct and indirect holdings of assets traded domestically and internationally. In Cesarini, Johannesson, Lichtenstein, Sandewall, and Wallace (forthcoming), individuals can only choose a maximum of five funds from a list of approximately 450 diversified mutual funds available to investors in the recently introduced public retirement system. This potentially results in more measurement error as some individuals cannot attain their preferred risk provided the constraints.

Our research is also related to a small but rapidly growing literature on gene-mapping and on the neural foundations of financial risk-taking.[6] Researchers in this field examine whether the presence of specific gene(s) may explain differences in risk-taking behavior in the cross-section of individuals. This work is motivated by recent studies which suggest that genes regulate specific "feel-good" neurotransmitters, e.g., dopamine, and affect the processing of information about rewarding. Taking more risk may result in more or longer-lasting production of these neurotransmitters depending on an individual's genetic composition. Thus, risk-taking may be experienced as more rewarding by individuals with specific genes, making them take more risk.

Two recent papers in this literature are Kuhnen and Chiao (2009) and Dreber, Apicella, Eisenberg, Garcia, and Zamore (2009). Kuhnen and Chiao (2009) elicit financial risk preferences using experiments and find that those who carry particular alleles of two genes display significantly different financial risk-taking behavior

[4] See Levitt and List (2007) for a general discussion of strengths of, and potential problems with, experimental approaches in economic research.

[5] The main measure in Cesarini, Johannesson, Lichtenstein, Sandewall, and Wallace (forthcoming, p. 5) is "Risk 1," defined as "the average risk level of the funds invested in by the individual, with the risk of each fund measured as the (annualized) standard deviation of the monthly rate of return over the previous three years."

[6] For an overview of how neurological systems play a role for a variety of behaviors of interest to economists, see, e.g., Camerer, Loewenstein, and Prelec (2005).

compared to those who do not have those alleles. Dreber, Apicella, Eisenberg, Garcia, and Zamore (2009) report similar results. In addition, Zhong, Israel, Xue, Ebstein, and Chew (2009) link a specific gene to individual preferences over gambles with a small probability of a substantial payoff. While gene-mapping can uncover which specific genes matter, it cannot quantify the relative importance of genetic and environmental components for investment behavior.

2.2. The genetic component of determinants of investment behavior

Financial economists have identified a number of individual characteristics, which in addition to preferences for risk-taking, explain investment behavior. At the same time, behavioral genetics researchers have examined many of the very same characteristics, but from the perspective of whether they have a significant genetic component.[7] In Table 1, we summarize existing empirical evidence from these literatures. The table reviews several individual characteristics related to investment behaviors (stock market participation and asset allocation) and reports the range of the magnitude of the genetic component based on behavioral genetics research.[8]

Existing research has shown that stock market participation is determined by factors that allow an individual to overcome entry barriers, such as wealth, education, cognitive abilities, social interaction, and trust, as well as an individual's risk aversion and background risks. As Table 1 makes clear, almost all of these have been found to have a significant genetic component. Consider, for example, intelligence quotient (IQ). Grinblatt, Keloharju, and Linnainmaa (2009) find that IQ is positively related to stock market participation while IQ has long been recognized as having a significant genetic component (see, e.g., Burt, 1966; Scarr and Weinberg, 1978).[9] Another specific example is social interaction. Hong, Kubik, and Stein (2004) show that social interaction is positively related to stock market participation possibly because learning from friends and neighbors may reduce fixed participation costs.[10] At the same time, researchers have shown that "Extraversion," one of Eysenck's and the Big Five personality traits, and related to sociability, has a significant genetic component (e.g., Eaves and Eysenck, 1975; Jang, Livesley, and Vernon, 1996).[11] We refer to the table for a review of additional characteristics and references to existing research. We conclude that a finding of a genetic component of stock market participation may reflect that effective participation costs are, in part, genetically determined.

The table also reviews factors which have been found to be related to financial risk-taking (typically measured as the share of financial assets invested in equities or more generally risky financial assets). In addition to risk aversion and wealth, several background risk factors have been proposed: labor income risk, entrepreneurial activity, health status, and marital status. Vissing-Jørgensen (2002b) finds that the volatility of non-financial income is negatively related to share in equities. Heaton and Lucas (2000) find that entrepreneurial activity is related to a smaller equity share, possibly because of the idiosyncratic and non-insurable risk it exposes the individual to. Research in entrepreneurship and behavioral genetics reports that the choice to become self-employed has a significant genetic component (e.g., Nicolaou, Shane, Cherkas, Hunkin, and Spector, 2008; Zhang, Zyphur, Narayanan, Arvey, Chaturvedi, Avolio, Lichtenstein, and Larsson, 2009). Health status is another characteristic that has been found to be related to share in equities. For example, Rosen and Wu (2004) find that poor health status results in a smaller share invested in equities, all else equal. A large number of studies have shown that the causes of common diseases such as heart disease (e.g., Marenberg, Risch, Berkman, Floderus, and de Faire, 1994), various forms of cancer (e.g., Lichtenstein, Holm, Verkasalo, Iliadou, Kaprio, Koskenvuo, Pukkala, Skytthe, and Hemminki, 2000), and rheumatoid arthritis (e.g., MacGregor, Snieder, Rigby, Koskenvuo, Kaprio, Aho, and Silman, 2001) have a significant genetic component. Marital status has also been found to affect asset allocation decisions (Love, 2010), and seems to be partly determined by genes (e.g., McGue and Lykken, 1992; Jockin, McGue, and Lykken, 1996). A finding of a genetic component of measures of asset allocation such as share in equities and portfolio volatility may reflect genetically determined differences in risk preferences or exposure to background risk factors.[12]

A review of the behavioral genetics literature results in three main conclusions. First, most individual characteristics related to investment behavior seem to have a significant genetic component, explaining as much as 95% of the variance in some characteristic. We interpret the results in the table as indirect evidence of a relation between genes and investment behavior. Second, for

[7] The genetics of complex personality traits started to be researched using twin studies with the seminal contribution of Loehlin and Nichols (1976). For an extensive review of recent twins studies related to personality traits, see, e.g., Plomin and Caspi (1999) and the references therein.

[8] Several recent papers have studied individuals' trading behavior in brokerage accounts or overall portfolios (e.g., Odean, 1998a, 1998b, 1999; Barber and Odean, 2000, 2001; Grinblatt and Keloharju, 2000, 2001, 2009). We do not have data on individuals' trading and can therefore not examine genetics and trading behavior in this paper.

[9] In a review of 111 studies, Bouchard and McGue (1981) find reported heritability of IQ ranging from 0.40 to 0.80. McClearn, Johansson, Berg, Pedersen, Ahern, Petrill, and Plomin (1997) show a genetic component of cognitive ability also in twins 80 years or older.

[10] For evidence on "peer effects" in the context of financial decisions, see also Madrian and Shea (2000), Duflo and Saez (2002), and Brown, Ivković, Smith, and Weisbenner (2008).

[11] For research on genetics and personality, see, e.g., Tellegen, Lykken, Bouchard, Wilcox, and Segal (1988) and Loehlin, McCrae, and Costa (1998).

[12] Several studies suggest that an individual can be predisposed to certain investment behaviors. For example, Sundén and Surette (1998) and Barber and Odean (2001) find gender-based differences in asset allocation and trading. However, from this evidence it is not possible to infer whether gender is the only, or most important, genetic component of investment behavior. Men and women could also be treated differently when growing up, systematically affecting their behavior in financial markets.

Table 1
Summary of empirical evidence.
The table summarizes existing empirical evidence from the financial economics and behavioral genetics literatures. The table reviews several individual characteristics related to investment behaviors (stock market participation and asset allocation) and reports the range of the magnitude of the genetic component based on behavioral genetics research.

	Finance/economics		Heritability	Behavioral genetics
	Stock market participation	Asset allocation		References
Risk aversion	Charles and Hurst (2003)	Barsky, Juster, Kimball, and Shapiro (1997)	20–63%	Cesarini, Dawes, Johannesson, Lichtenstein, and Wallace (2009a), Dreber, Apicella, Eisenberg, Garcia, and Zamore (2009), Kuhnen and Chiao (2009), Zhong, Israel, Xue, Ebstein, and Chew (2009), Zyphur, Narayanan, Arvey, and Alexander (2009)
Wealth	Mankiw and Zeldes (1991), Guiso, Haliassos, and Jappelli (2001), Vissing-Jørgensen (2002b)	Friend and Blume (1975), Poterba and Samwick (1995)	5–52%	Behrman and Taubman (1976)
Education, schooling, financial literacy	Haliassos and Bertaut (1995), Bernheim, Garrett, and Maki (2001), Bernheim and Garrett (2003), Van Rooij, Lusardi, and Alessie (2007), Campbell (2006)		N/A	Behrman and Taubman (1989), Ashenfelter and Krueger (1994), Ashenfelter and Rouse (1998), Björklund, Lindahl, and Plug (2006)
Cognitive ability, IQ	Grinblatt, Keloharju, and Linnainmaa (2009)		40–85%	Burt (1966), Scarr and Weinberg (1978), Horn, Loehlin, and Willerman (1982), Bouchard and McGue (1981), McClearn, Johansson, Berg, Pedersen, Ahern, Petrill, and Plomin (1997), Bouchard (1998)
Extraversion, sociability	Hong, Kubik, and Stein (2004)		51–57%	Eaves and Eysenck (1975), Jang, Livesley, and Vernon (1996), Tellegen, Lykken, Bouchard, Wilcox, and Segal (1988), Loehlin, McCrae, and Costa (1998), Riemann, Angleitner, and Strelau (1997)
Trust	Guiso, Sapienza, and Zingales (2008)	Guiso, Sapienza, and Zingales (2008)	10–32%	Cesarini, Dawes, Fowler, Johannesson, Lichtenstein, and Wallace (2008)
Gambling	Kumar (2009)		35–54%	Eisen, Lin, Lyons, Scherrer, Griffith, and True (1998), Ibáñez, Blanco, Perezde Castro, Fernandez-Piqueras, and Sáiz-Ruiz (2003)
Labor income risk	Haliassos and Bertaut (1995), Vissing-Jørgensen (2002a), Campbell (2006)	Vissing-Jørgensen (2002b), Campbell (2006)	N/A	
Entrepreneurship		Heaton and Lucas (2000)	37–42%	Nicolaou, Shane, Cherkas, Hunkin, and Spector (2008), Zhang, Zyphur, Narayanan, Arvey, Chaturvedi, Avolio, Lichtenstein, and Larsson (2009)
Health		Rosen and Wu (2004)	10–97%	Marenberg, Risch, Berkman, Floderus, and de Faire (1994), Lichtenstein, Holm, Verkasalo, Iliadou, Kaprio, Koskenvuo, Pukkala, Skytthe, and Hemminki (2000), MacGregor, Snieder, Rigby, Koskenvuo, Kaprio, Aho, and Silman (2001)
Height	Korniotis and Kumar (2009)	Korniotis and Kumar (2009)	60–80%	Silventoinen (2003)
Marital status		Love (2010)	0–53%	McGue and Lykken (1992), Jockin, McGue, and Lykken (1996)

many of the characteristics studied, there is not much evidence to suggest that the shared environment, i.e., the effects of growing up in the same family, has significant impact on investment behavior.[13] Some studies find a significant effect of family environmental influence in early ages, but it approaches zero in adulthood (e.g., Bouchard, 1998). In contrast, behavioral genetics researchers have found significant effects of the non-shared environment, i.e., idiosyncratic environmental stimuli that are experienced by one individual. Finally, some research in psychology shows that the proportion of the variation in personality traits explained by a genetic factor generally decreases with age (e.g., Viken, Rose, Kaprio, and Koshenvuo, 1994).

[13] Sacerdote (2002) finds that adoptive parents' education and income have a modest effect on child test scores but a larger effect on education, labor income, and marital status. Using data on adopted children, Sacerdote (2007) also finds significant effects of nurture on outcomes such as educational attainment and drinking behavior.

3. Quantifying genetic and environmental effects

In order to decompose the heterogeneity in investment behavior into genetic and environmental components, we investigate the behavior of pairs of identical and fraternal twins. When a behavior has a significant genetic component, the correlation among identical twins is greater than the correlation among fraternal twins. Identical (monozygotic, MZ) twins share 100% of their genetic composition, while the average proportion of shared genes is only 50% for fraternal (dizygotic, DZ) twins. As we explain in more detail below, the identification strategy in this paper relies on these standard genetics facts.

We assume the following model for a measure of investment behavior (y):

$$y_{ij} = \beta_0 + \beta \mathbf{X}_{ij} + a_{ij} + c_i + e_{ij}, \tag{1}$$

where i indexes a twin pair and j (1 or 2) indexes one of the twins in a pair. β_0 is an intercept term and β measures the effects of the included covariates ($\mathbf{X}_{ij}$). a_{ij} and c_i are unobservable random effects, representing an additive genetic effect and the effect of the environment shared by both twins, respectively. e_{ij} is an individual-specific error term that represents the non-shared environmental effects as well as any measurement error. This model is the most commonly used model in quantitative behavioral genetics research, and referred to as an "ACE model." A stands for additive genetic effects, C for shared (common) environment, and E for non-shared environment.

The model assumes that a, c, and e (the subscripts are suppressed for convenience) are independently normally distributed with means of zero and variances σ_a^2, σ_c^2, and σ_e^2, respectively, so that the residual variance is the sum of three variance components, $\sigma_a^2+\sigma_c^2+\sigma_e^2$. Identification of σ_a^2 and σ_c^2 is possible because of the covariance structure implied by genetic theory.

Consider two unrelated twin pairs i=1,2 with twins j=1,2 in each pair, where the first pair is identical twins and the second pair is fraternal twins. The corresponding genetic components are denoted by $\mathbf{a} = (a_{11}, a_{21}, a_{12}, a_{22})'$. Analogously, the vectors of shared and non-shared environment effects are defined as $\mathbf{c} = (c_{11}, c_{21}, c_{12}, c_{22})'$ and $\mathbf{e} = (e_{11}, e_{21}, e_{12}, e_{22})'$, respectively. Assuming a linear relation between genetic and behavioral similarity, genetic theory suggests the following covariance matrices:

$$\mathrm{Cov}(\mathbf{a}) = \sigma_a^2 \begin{bmatrix} 1 & 1 & 0 & 0 \\ 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1/2 \\ 0 & 0 & 1/2 & 1 \end{bmatrix}, \quad \mathrm{Cov}(\mathbf{c}) = \sigma_c^2 \begin{bmatrix} 1 & 1 & 0 & 0 \\ 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 \\ 0 & 0 & 1 & 1 \end{bmatrix},$$

$$\mathrm{Cov}(\mathbf{e}) = \sigma_e^2 \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}.$$

The described model is very similar to a general random effects model, with the difference being that the covariance matrices of the random effects in this case depend on the type of the twin pair (identical versus fraternal).

We use maximum likelihood estimation (MLE) to obtain the parameters of the model (see, e.g., Feng, Zhou, Zhang, and Zhang, 2009, for details). We also calculate the sum of the three variances σ_a^2, σ_c^2, and σ_e^2, as well as the proportion of the residual variance attributable to genetic effects, the shared environment, and the non-shared environment. The proportion of the variance attributable to the additive genetic component, called heritability, is

$$A = \frac{\sigma_a^2}{\sigma_a^2+\sigma_c^2+\sigma_e^2}.$$

We compute the proportion of the variance attributable to σ_c^2 and σ_e^2 analogously. These three proportions, which we refer to as the A, C, and E variance components, are the estimates of main interest in this study.

There are several assumptions behind this standard model. First, all genetic effects are additive, i.e., a "dominant" gene is not important for the analyzed behavior.[14] We address the validity of this assumption in detail in our robustness section. Second, we assume in Eq. (1) that the relative importance of the different variance components does not depend on age, gender, or environmental circumstances. We examine this assumption by estimating our model for different subsets. Finally, we assume that identical and fraternal twins vary only in their genetic relatedness, but not in the effect the shared environment has on them. If, for example, identical twins interact socially more than fraternal twins or if parents treat identical twins differently from fraternal twins, then this assumption may be violated and may result in an upward bias of the genetic component. We address this assumption by explicitly controlling for twin contact intensity and by studying twins that were reared apart.

4. Data

4.1. The Swedish Twin Registry

We use data on twins from the Swedish Twin Registry (STR), managed and maintained by Karolinska Institutet in Stockholm, Sweden. The STR is the world's largest database of twins. The registry is compiled by the STR obtaining data on all twins' births from national databases of birth records in Sweden. The STR is recognized worldwide for the quality of its data, which have been used in a large number of published research papers in different fields.

STR's databases are organized by birth cohort. The *Screening Across Lifespan Twin*, or "SALT," database contains data on twins born 1886–1958. The *Swedish Twin Studies of Adults: Genes and Environment* database, or "STAGE," contains data on twins born 1959–1985. In addition to twin pairs, twin identifiers, and zygosity

[14] This implies that our model assumes that the correlation between identical twins is at most twice the correlation of fraternal twins and at least the same. Formally, $\rho_{MZ}/\rho_{DZ} = (\sigma_a^2+\sigma_c^2)/(\frac{1}{2}\sigma_a^2+\sigma_c^2)$ has to fall into [1,2] as the variance terms cannot be negative.

status,[15] the databases contain variables based on STR's telephone interviews (for SALT), completed 1998–2002, and combined telephone interviews and Internet surveys (for STAGE), completed 2005–2006. The participation rate in SALT, for the 1926–1958 cohort, was 74%. The participation rate in STAGE was also high, 60%, in spite of the fact that a very large number of questions (approximately 1,300) were asked. For further details about STR, we refer to Lichtenstein, Sullivan, Cnattingius, Gatz, Johansson, Carlström, Björk, Svartengren, Wolk, Klareskog, de Faire, Schalling, Palmgren, and Pedersen (2006).

4.2. Data on twins

Table 2 reports summary statistics for our data set of twins. All data refer to the year 2002. The minimum age to be included in our sample is 18. We report summary statistics only for twin pairs with complete data, i.e., pairs for which both twins were alive in 2002, and for which data on individual portfolio choices are available.[16]

Panel A shows the number of twins by category and gender. In total, there are 37,504 twins. Split by zygosity status, we see that 10,842 (29%) are identical twins, while 26,662 (71%) are fraternal twins. Moreover, we see that opposite-sex twins are the most common twin type (38%), and identical male twins are the least common type (12%). The evidence in the table on the relative frequency of different types of twins is consistent with that from other studies that use large samples of twins.

Panel B reports summary statistics for characteristics of individuals.[17] Definitions of all variables are available in the Appendix. We construct three education indicator variables based on an individual's highest level of education: at most nine years of schooling (*Education level* 1), college (*Education level* 2), and graduate degree (*Education level* 3). *Disposable income* is the disposable income of the individual's household. *Net worth* is the difference between the market value of an individual's assets and liabilities. *Business owner* is an indicator variable that equals one if an individual's income from active business activity is more than 50% of the individual's labor income, and zero otherwise. *Home owner* is an indicator variable that equals one if the market value of owner-occupied real estate is positive, and zero otherwise. *Retired* is an indicator variable that equals one if an individual receives retirement income, and zero otherwise. *Poor health* is an indicator variable that equals one if an individual receives payments due to illness, injury, or disability, and zero otherwise. *Single* is an indicator variable that equals one if an individual is neither married nor in a registered partnership, and zero otherwise. *Family size* is the total number of people in a household. Comparing identical and fraternal twins, we see that they are generally similar.

We also compare the samples of twins to the general population. In the table, we report characteristics of a random sample of the same size (37,504 non-twins) and with the same age distribution. Specifically, for each twin in our data set, we randomly selected a non-twin of the exact same age from the Swedish population. We conclude that twins seem to be representative of the general population in terms of individual characteristics.

4.3. Data on portfolio choices

The data on individuals' portfolios are from the Swedish Tax Agency. Until 2006, households in Sweden were subject to a 1.5% wealth tax on asset ownership (other than ownership of a business which is not included in taxable wealth) above a threshold of SEK 3 million (or about $343,000 at the exchange rate of 8.7413 Swedish Krona per dollar as of 12/31/2002) for married tax filers and SEK 1,500,000 for single filers. When an asset is jointly owned by two or more tax filers, the market value is split between the tax filers. Until the abolishment of the wealth tax, the law required all Swedish financial institutions to report information to the Tax Agency about the securities (including bank account balances) an individual owned as of December 31 of that year.[18] Statistics Sweden matched twins with their portfolios using *personnummer* (the equivalent of a Social Security number in the U.S.) as the unique individual identifier.

For each financial security owned by an individual, our data set contains data on both the number of securities and each security's International Security Identification Number (ISIN). We obtain daily return data for these assets from a large number of sources, including Bloomberg, Datastream, and the Swedish Investment Fund Association (Fondbolagens Förening).

Table 3 reports summary statistics for twins' portfolio choices. We split the twins by zygosity type in the first set of columns in the table. In the final set of columns, we report summary statistics for the random sample of 37,504 Swedish individuals. The average portfolio value of identical and fraternal twins is similar: $29,987 and $33,264, respectively.

In Panel A, we examine how their financial assets are allocated. We report the proportion of financial assets in cash (i.e., bank account balances and money market funds), bonds and fixed income securities, equities (direct versus funds), options, and "other financial assets."[19] Cash is the most common asset in the portfolios (42% and 43%

[15] Zygosity is based on questions about intrapair similarities in childhood. One of the survey questions is: "Were you and your twin partner during childhood 'as alike as two peas in a pod' or were you 'no more alike than siblings in general' with regard to appearance?" This method has been validated with DNA as having 98% or higher accuracy. For twin pairs for which DNA sampling has been conducted, zygosity status based on DNA analysis is used.

[16] Because of in vitro fertilization, the number of fraternal twin births has increased in recent decades, but this technological progress largely took place after the last birth cohort year included in our data set.

[17] The size of the samples (*N*) differs across columns because of data availability.

[18] A comprehensive analysis of individual portfolio choice data from Sweden has recently been performed by Calvet, Campbell, and Sodini (2007, 2009).

[19] Cash in bank accounts with a balance of less than SEK 10,000 (or for which the interest was less than SEK 100 during the year). However, Statistics Sweden's estimations suggest that 98% of all cash in bank accounts is included in the data. The class called "other financial assets" includes rights, convertibles, and warrants.

Table 2
Summary statistics: twins.

Panel A reports the number of twins by zygosity (identical vs. fraternal), birth cohort, and gender. Panel B reports cross-sectional means and standard deviations for the sample of all twins as well as for a random sample of age-matched non-twins. *N* provides the number of observations. All data refer to 2002. See Appendix for a detailed definition of all variables.

Panel A: Number of twins by zygosity and gender									
Birth cohort	Data set	Identical twins			Non-identical twins				All twins
		Male	Female	Total	Same sex: Male	Same sex: Female	Opposite sex	Total	
1886–1958	SALT	2,692	3,752	6,444	4,018	5,326	11,234	20,578	27,022
1959–1986	STAGE	1,810	2,588	4,398	1,250	1,816	3,018	6,084	10,482
Total (*N*)		4,502	6,340	10,842	5,268	7,142	14,252	26,662	37,504
Total (%)		12%	17%	29%	14%	19%	38%	71%	100%

Panel B: Individual characteristics								
	All twins	Identical twins		Non-identical twins		Random sample of non-twins		
Variable	*N*	Mean	Std. dev.	Mean	Std. dev.	*N*	Mean	Std. dev.
Age	37,504	48.69	18.15	54.54	15.81	37,504	52.85	16.74
Education level 1	33,371	0.17	0.38	0.24	0.43	33,244	0.23	0.42
Education level 2	33,371	0.45	0.50	0.44	0.50	33,244	0.46	0.50
Education level 3	33,371	0.37	0.48	0.32	0.47	33,244	0.31	0.46
Disposable income (USD)	37,504	36,984	39,340	36,113	43,080	37,504	37,267	142,789
Net worth (USD)	37,504	71,803	176,511	82,615	331,594	37,504	86,967	1,529,036
Business owner	37,504	0.02	0.14	0.03	0.16	37,504	0.03	0.16
Home owner	37,504	0.57	0.49	0.61	0.49	37,504	0.59	0.49
Retired	37,504	0.30	0.46	0.38	0.49	37,504	0.37	0.48
Poor health	37,504	0.14	0.35	0.15	0.36	37,504	0.17	0.38
Single	37,504	0.54	0.50	0.46	0.50	37,504	0.47	0.50
Family size	37,504	2.31	1.31	2.21	1.21	37,504	2.25	1.22

Table 3
Summary statistics: portfolio choices.

Panel A reports cross-sectional means and standard deviations of the amount of financial assets held and the relative investments in different assets for the sample of 37,504 twins as well as for a random sample of 37,504 age-matched non-twins. Panel B reports cross-sectional means and standard deviations of three measures of investment and financial risk taking behavior: Stock market participant, a binary indicator of whether an investor holds any equities, Share in equities, the fraction of financial assets invested in equities conditional on being an equity holder, and Volatility, the annualized daily time-series volatility of an investor's equity portfolio. *N* provides the number of observations. All data refer to 2002. See Appendix for a detailed definition of all variables.

Variable	All twins	Identical twins		Fraternal twins		Random sample of non-twins		
	N	Mean	Std. dev.	Mean	Std. dev.	*N*	Mean	Std. dev.
Panel A: Asset allocations								
Proportion of financial assets:								
– in cash	37,504	0.42	0.38	0.43	0.39	37,504	0.44	0.39
– in bonds	37,504	0.04	0.13	0.04	0.14	37,504	0.04	0.14
– in equities (direct)	37,504	0.12	0.24	0.12	0.25	37,504	0.13	0.26
– in equities (funds)	37,504	0.35	0.36	0.33	0.36	37,504	0.31	0.36
– in options	37,504	0.00	0.01	0.00	0.01	37,504	0.00	0.01
– in other	37,504	0.08	0.21	0.08	0.21	37,504	0.08	0.21
Panel B: Measures of investment and financial risk-taking behavior								
Stock market participant	37,504	0.80	0.40	0.78	0.41	37,504	0.76	0.43
Share in equities	24,396	0.59	0.34	0.57	0.34	22,500	0.58	0.35
Volatility	10,830	0.18	0.10	0.18	0.10	9,102	0.19	0.11

for identical and fraternal twins), followed by stock funds which at the mean constitute 35% and 33% for identical and fraternal twins, and then direct ownership of stocks (12% for both identical and fraternal twins). We find that the compositions of twins' portfolios are generally very similar to those in the random sample.

In Panel B, we report summary statistics for the measures of asset investment behavior that we analyze. *Stock market participant* is an indicator variable that is one if the investor holds any investment in equities, and zero otherwise. *Share in equities* is the proportion of financial assets invested in equities conditional on being a stock market participant.[20] We use this measure because of its

[20] Note that the sum of the "Proportion of financial assets in equities (direct)" and the "Proportion of financial assets in equities (funds)," in Panel A is not equal to *Share in equities* in Panel B because of the conditioning on stock market participation in Panel B.

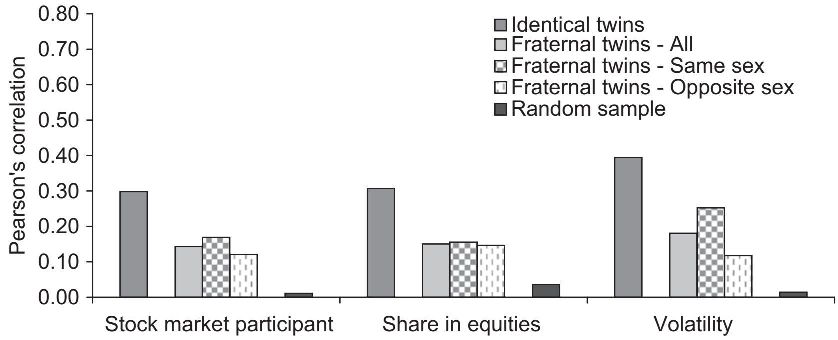

Fig. 1. Pearson's correlations for Stock market participant, Share in equities, and Volatility among twins by genetic similarity (identical, fraternal-all, fraternal-same sex, and fraternal-opposite sex), and among pairs in a random sample of age-matched non-twins. All data refer to 2002. See Appendix for a detailed definition of all variables.

theoretical relation with an individual's risk-aversion coefficient (γ). In a standard asset allocation model, assuming constant relative risk-aversion (CRRA) and independently and identically distributed asset returns, it can be shown that $1/\gamma_i$ for individual i is proportional to the share that the individual invests in risky assets. That is, the genetic component of the share of risky assets is a measure of the percentage of an investor's risk aversion coefficient that can be explained by genes. We also consider a "model-independent" measure of asset allocation: *Volatility*, the annualized daily time-series volatility of an investor's equity portfolio.

We find that the twins are very similar on the measures of investment behavior reported in the table: 80% (78%) of identical (fraternal) twins invest in the stock market.[21] At the mean, *Share in equities* is 59% and 57%, respectively, for identical and fraternal twins. The annualized portfolio volatility is 18%, on average, for both identical and fraternal twins. Finally, the table shows that the means for our sample of twins are generally within a few percentage points of the means of the random sample.

5. Empirical results

5.1. Identical and fraternal twin pair correlations

We start our empirical analysis by reporting separate Pearson's correlation coefficients for identical and fraternal twin pairs for the three measures of investment behavior studied in this paper: *Stock market participant*, *Share in equities*, and *Volatility*. These correlations provide a first and intuitive indication of whether these investment behaviors have a genetic component. For fraternal twins, we report correlations for both same-sex and opposite-sex twins. Finally, we also report the correlations between twins and random age-matched non-twins from the population. The correlations between twins and their random match pairs capture potential life-cycle effects in investment behavior.

[21] Relative to the U.S., stock market participation is high in Sweden (Guiso, Haliassos, and Jappelli, 2001).

Fig. 1 shows the correlation results. There are three conclusions that can be drawn from the figure. First, for each measure, we find that the correlation is substantially greater for identical twins than for fraternal twins, indicating a substantial genetic component for all the measures studied. The differences are statistically significant at the 1%-level. For *Stock market participant*, the correlation among pairs of identical twins is 0.298, compared to only 0.143 for fraternal twins. For *Share in equities*, the finding is similar: the correlation among identical twins is 0.307, significantly higher than the correlation among fraternal twin pairs, which is 0.150. Finally, for *Volatility* we find that the correlation for identical twins is 0.394, compared to 0.181 for fraternal twins.

Second, for fraternal twins, the correlations are greater for same-sex twins compared to opposite-sex twins. The p-values for statistically significant differences are 0.005, 0.674, and 0.000, respectively, for *Stock market participant*, *Share in equities*, and *Volatility*. Our interpretation of this result is that gender-based differences are present in the investment behaviors studied (Sundén and Surette, 1998; Barber and Odean, 2001). Because of such possible gender differences, we will include gender as a covariate in our formal statistical analysis.

Finally, the correlation between twins and their age-matched non-twin pairs is significantly lower than the correlations among identical or fraternal twin pairs. On average, these correlations are only 0.020. The slight positive correlation may be explained by life-cycle effects in portfolio choices (e.g., Ameriks and Zeldes, 2004). That is, two randomly selected individuals of the same age have somewhat similar portfolio choices because of life-cycle effects in investment behavior. We will therefore include age and age-squared as covariates in our analysis.

The correlation results reported so far are an indication that the probability of investing in the stock market and the propensity to take on financial risk in one's investment portfolio is explained, at least in part, by a significant genetic factor. Importantly, there is also evidence of environmental influences because identical twin correlations are considerably less than one. Next, we therefore estimate the relative importance of genes and the environment.

5.2. Decomposing the cross-sectional variance of investment behavior

5.2.1. Estimates from random effects models

As described in Section 3, we can decompose the variance in each of the measures of investment behavior into three components: an additive genetic component (*A*), a common environmental component (*C*), which is shared by both twins, for example their parental upbringing, and a non-shared environmental component (*E*).

Table 4 reports the estimates from the maximum likelihood estimation, with one measure in each panel. We estimate the parameters of the model specification in Eq. (1), controlling for *Male*, *Age*, and *Age-squared*, because of the gender and age effects in financial behavior noted above. This allows us to estimate the proportion of the residual variance attributable to the three components, *A*, *C*, and *E*. For *A*, the table reports $\sigma_a^2/(\sigma_a^2+\sigma_c^2+\sigma_e^2)$, the proportion of the total variance attributable to an additive genetic factor. We compute the proportion of the variance attributable to *C* and *E* analogously. The first row of each panel reports an E model, in which the additive genetic effect and the effect of the shared environment are constrained to zero. The second row reports a CE model, in which the additive genetic effect is constrained to zero and the final row reports the full ACE model. To enable comparisons of model fit across model specifications, we report the Akaike Information Criterion (AIC) for each model. We also report the likelihood ratio (LR) test statistics and the associated *p*-values for comparing the E model against the CE model and the CE model against the ACE model.

We draw three conclusions from the table. First, when we compare the fit of the estimated models (E versus CE versus ACE models), we find that the ACE model is always preferred based on the AIC, i.e., the ACE model has the lowest AIC. Based on the LR test, we also find that in all cases the E model is rejected at the 1%-level in favor of a CE model, which in turn is rejected in favor of an ACE model. That is, including a latent genetic factor is important if we want to understand and explain the cross-sectional heterogeneity in investment behavior in financial markets.

Second, we find that the genetic component, *A*, of investment behavior is statistically significant and that the magnitude of the estimated effect is large. That is, we discover a substantial genetic component across all of the financial behaviors studied. For *Stock market participant* (Panel A), the estimate of *A* is 0.287, and statistically significant at the 1%-level. For *Share in equities* (Panel B), the genetic component is 0.283. In a simple asset pricing model, the genetic component of the proportion of risky assets is a measure of the proportion of the variation in investors' risk aversion that can be explained by genes and not the environment because γ_i is inversely proportional to investor *i*'s proportion invested in risky assets. Thus, one interpretation of our results is that about 28% of the total variance in risk aversion across individual investors is attributable to a genetic factor. We also consider a measure of risk-taking in financial markets that is model-independent: *Volatility* measured as the annualized daily time-series volatility of an investor's equity portfolio. We analyze this measure in Panel C of Table 4 and find that genes are again important, as the estimate of *A* is 0.370.

We find that the shared environmental factor, *C*, is estimated to be zero for all three measures of investor behavior.[22] This suggests that, on average, differences in nurture (i.e., the common environment twins grew up in)

Table 4

Heritability of investment and financial risk-taking behavior.

The table reports results from maximum likelihood estimation of linear random effects models. The model is estimated using data on up to 37,504 Swedish twins. Stock market participant (Panel A), Share in equities (Panel B), and Volatility (Panel C) are modeled as linear functions of *Male*, *Age*, *Age-squared*, as well as up to three random effects representing additive genetic effects, shared environmental effects, and an individual-specific error. In each panel, we report results for a model that only allows for an individual-specific random effect (E model), a model that also allows for a shared environmental effect (CE model), and a model that also allows for an additive genetic effect (ACE model). When the non-negativity constraint for a variance parameter is binding, we report a zero. In each case, we report Akaike's information criterion (AIC), the variance fraction of the combined error term explained by each random effect (*A*—for the additive genetic effects, *C*—for shared environmental effects, *E*—for the individual-specific random effect), as well as the corresponding standard errors. We perform likelihood ratio tests (LR) and at the 1% level reject all E models in favor of the corresponding CE models. We also reject all CE models in favor of the corresponding ACE models. We do not report the coefficient estimates for *Male*, *Age*, and *Age-squared. N* provides the number of observations used in each estimation. All data refer to 2002. See Appendix for a detailed definition of all variables.

Model	AIC	LR/*p*-value	Variance components		
			A	*C*	*E*
Panel A: Stock market participant (*N*=37,504)					
E	38,968	592			1.0000
		0.00			
CE	38,378	116		0.1763	0.8237
		0.00		0.0071	0.0071
ACE	38,264		0.2866	0.0000	0.7134
			0.0102		0.0102
Panel B: Share in equities (*N*=24,396)					
E	69,603	401			1.0000
		0.00			
CE	69,203	75		0.1799	0.8201
		0.00		0.0088	0.0088
ACE	69,130		0.2825	0.0000	0.7175
			0.0123		0.0123
Panel C: Volatility (*N*=10,830)					
E	31,017	317			1.0000
		0.00			
CE	30,702	64		0.2385	0.7615
		0.00		0.0128	0.0128
ACE	30,640		0.3696	0.0000	0.6304
			0.0171		0.0171

[22] The non-negativity constraint for σ_c^2 is binding in all three cases, and given the constraint, σ_c^2 is optimally set to zero. The reported results are equivalent to estimating an AE model. We report *C* as zero to indicate that we did not impose an AE model, but that it was the outcome of the constrained optimization. For all three cases, we have confirmed that allowing σ_c^2 to take on negative values would not significantly improve the fit. That is, while σ_c^2 would take on negative values (if not

or the common environment they share as adults, do not contribute to explaining differences in investment behavior. This result is somewhat surprising as the family environment constitutes a natural source of information which could allow children to overcome fixed participation costs. While parents have a significant impact on their children's asset allocation and the riskiness of chosen portfolios, this influence is found to be through their genes and not through parenting or other non-genetic sources.

Finally, we find that *E*, the non-shared environment, i.e., the individual experiences and non-genetic circumstances of one twin that are not equally shared by the other twin, contribute substantially to the observed heterogeneity. For *Stock market participant*, the non-shared component is 0.713. For *Share in equities*, it is 0.718, and for *Volatility*, it is 0.630.

5.2.2. Effects of including covariates

In Table 5, we estimate our model with a large set of additional controls. Our goal is twofold. First, we wish to contrast the importance of the latent genetic effect with the contribution of observable investor characteristics typically employed in empirical studies. Second, and in particular with respect to our two measures of financial risk-taking, we want to account for all factors other than risk aversion. Doing so allows us to obtain a more precise estimate of the genetic component of investors' risk aversion or more generally, risk preferences. In the section of the table entitled "Mean," we report the parameter estimates and standard errors for β_0 and β in Eq. (1), which measures the effects of the covariates on the mean of the measure studied. In the first column for each measure (columns 1, 3, and 6 in the table), we do not include any covariates. In the following column for each measure (columns 2, 4, and 7), we include *Male*, *Age*, and *Age-squared*, as well as the additional controls *Education level* 2, *Education level* 3, *Net worth*, *Business owner*, *Home owner*, *Retired*, *Poor health*, *Single*, and *Family size*.[23]

Because we observe *Share in equities* and *Volatility* only for stock market participants, the coefficient estimates for those two measures could potentially be biased due to sample selection. In the final column for these two measures (columns 5 and 8), we therefore report results from using Heckman's (1976) two-stage sample selection approach. In the first stage, we estimate a probit model for stock market participation. In addition to the controls used in the second stage, the probit specification also includes disposable income as an explanatory variable.

Focusing on columns 2, 5, and 8, we find that men are more likely to invest in the stock market, invest a larger fraction of their financial assets in equities, and hold more volatile equity portfolios. Consistent with previous research, we find that *Stock market participant*, *Share in equities*, and *Volatility* increase in educational achievement as well as net worth. Business owners are more likely to invest in the stock market, but hold a smaller fraction of their financial assets in equities, while home ownership is positively associated with being an equity holder and investing in equities. Retirees and individuals with health problems are less likely to participate in the stock market and hold a smaller fraction of their financial wealth in equities. Being single seems to lower the probability of stock market participation, without affecting asset allocation choices. *Family size*, on the other hand, is positively associated with *Share in equities*. Finally, we observe that the coefficients on the inverse Mills' ratio are statistically significant, suggesting that controlling for sample selection is important.

In the section of the table entitled "Residual variance," we report the variance of the combined error term, i.e., we report the sum of σ_a^2, σ_c^2, and σ_e^2. In columns 1, 3, and 6, the residual variance equals the total variance of the dependent variable. To the extent that the explanatory variables explain the variation of the dependent variable, the residual variance decreases as explanatory variables are added. Examining the residual variances in columns 2, 5, and 8, it is apparent that the explanatory power (measured as the reduction in the residual variance between columns 1 and 2, 3 and 5, as well as 6 and 8) of the included investor characteristics is small, ranging between 1.4% for *Stock Market Participant* and 3.6% for *Share in Equities*.[24]

Finally, the decomposition of the residual variance suggests that even after controlling for an extensive set of individual characteristics, we find a significant genetic component. Across these measures, the estimated *A* is about one-third of the residual variance, varying from 0.280 to 0.359. That is, adding a large set of covariates which themselves might be heritable, does not significantly alter our conclusions about the heritability of investment behavior.

5.2.3. Interpretation

How can we make sense of the results reported so far? The evidence that investment behavior has a significant genetic component raises the question of what the specific channels are via which genes cause individual differences in investment behavior.

The channels are somewhat different for different aspects of investment behavior. We start by discussing

(*footnote continued*)
constrained to non-negative values), we cannot reject that σ_c^2 is equal to zero.

[23] We have also explored other sources of background risk. For example, Vissing-Jørgensen (2002a) examines the effect of labor income volatility on stock market participation and allocation. We find that the volatility of non-capital income growth, computed over the 1998–2006 panel for individuals with at least five data points and available for only about half of our sample, has an insignificant effect.

[24] We use a linear probability model to model the binary choice whether to participate in the stock market. The *Pseudo-*R^2 from a probit model with the same explanatory variables is 16% which corresponds better to the consensus in the literature that entry costs are indeed an important explanation of the observed variation in stock market participation. The low explanatory power we report with respect to *Share in equities*, on the other hand, is consistent with largely unexplained variation reported in other recent studies. For example, Heaton and Lucas (2000) report an adjusted R^2 of 3%, while Brunnermier and Nagel (2008) report an adjusted R^2 of 2%. Higher R^2 is typically observed only when a lagged dependent variable is included.

Table 5
Understanding heterogeneity of investment and financial risk-taking behavior.

The table reports results from maximum likelihood estimation of linear random effects models. The model is estimated using data on up to 37,504 Swedish twins. Stock market participant, Share in equities, and Volatility are modeled as linear functions of observable characteristics, as well as three random effects representing additive genetic effects, shared environmental effects, and an individual-specific error. We report estimates and standard errors for the coefficients associated with the observable characteristics as well as for the variance of the combined error term (*Residual variance*). We also report estimates and standard errors for the fraction of the residual variance attributable to the additive genetic effects (*A*), the shared environmental effects (*C*), as well as the individual-specific error term (*E*). *N* provides the number of observations used in each estimation. All data refer to 2002. See Appendix for a detailed definition of all variables.

	Stock market participant		Share in equities			Volatility		
	1	2	3	4	5	6	7	8
Mean								
Intercept	0.8011	0.8494	0.5840	0.7238	0.5748	0.1815	0.1280	0.1495
	0.0024	0.0272	0.0025	0.0276	0.0287	0.0011	0.0117	0.0173
Male		0.0195		−0.0004	0.0160		0.0247	0.0251
		0.0045		0.0047	0.0048		0.0021	0.0021
Age (divided by 100)		−0.4771		−0.4321	−0.8543		0.1573	0.4801
		0.1189		0.1223	0.1239		0.0535	0.1979
Age-squared (divided by 1,000)		0.0480		0.0228	0.0669		−0.0201	−0.0474
		0.0133		0.0138	0.0139		0.0062	0.0173
Education level 2		0.0449		0.0046	0.0420		0.0135	0.0149
		0.0060		0.0064	0.0068		0.0028	0.0030
Education level 3		0.0836		0.0012	0.0710		0.0240	0.0290
		0.0066		0.0070	0.0080		0.0032	0.0043
Net worth (in million SEK)		0.0066		−0.0013	0.0032		0.0023	0.0038
		0.0008		0.0007	0.0007		0.0011	0.0014
Business owner		0.0128		−0.0628	−0.0508		0.0165	0.0106
		0.0134		0.0136	0.0136		0.0061	0.0070
Home owner		0.0371		−0.0190	0.0135		0.0007	−0.0044
		0.0049		0.0052	0.0055		0.0024	0.0039
Retired		−0.0210		−0.0307	−0.0478		−0.0019	0.0044
		0.0075		0.0078	0.0078		0.0037	0.0052
Poor health		−0.0331		0.0095	−0.0195		−0.0041	−0.0002
		0.0063		0.0066	0.0068		0.0030	0.0038
Single		−0.0104		0.0148	0.0069		−0.0028	−0.0016
		0.0055		0.0058	0.0057		0.0026	0.0027
Family size		−0.0034		0.0105	0.0079		0.0015	−0.0001
		0.0022		0.0022	0.0022		0.0009	0.0013
Inverse Mills' ratio					0.5579			−0.0927
					0.0323			0.0547
Residual variance	0.1593	0.1568	0.1159	0.1129	0.1114	0.0104	0.0101	0.0101
	0.0013	0.0012	0.0011	0.0011	0.0011	0.0002	0.0001	0.0001
Variance components								
A	0.2930	0.2799	0.3157	0.2903	0.2902	0.3795	0.3590	0.3588
	0.0108	0.0109	0.0125	0.0128	0.0128	0.0176	0.0179	0.0179
C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
E	0.7070	0.7201	0.6843	0.7097	0.7098	0.6205	0.6410	0.6412
	0.0108	0.0109	0.0125	0.0128	0.0128	0.0176	0.0179	0.0179
N	33,371	33,371	22,384	22,384	22,384	10,063	10,063	10,063

interpretations of the genetic component of stock market participation. Our results in Table 4 suggest that about 29% of the variation in stock market participation across investors is due to genetic differences. Models in finance suggest that variation in stock market participation arises because investors face entry barriers and differ in the probability with which they overcome these barriers. As discussed above, this probability depends on investors' ability to overcome these entry barriers (wealth, education, cognitive ability, sociability) as well as their incentives to do so (risk aversion, background risk, trust, etc.) Our results therefore reflect the genetic variation that has been found for most of these characteristics. In Table 5, we include several, but not all of these characteristics in our model, but find only a small drop in the genetic component. This suggests that additional factors that are unobservable to us, but matter for stock market participation, such as risk aversion, IQ, trust, or other personality traits not yet explored in the finance literature, have a substantial genetic component that matters for stock market participation. This conclusion is consistent with the evidence presented in Table 1.

We now turn to an interpretation of the genetic component of an individual's asset allocation (share in equities or portfolio volatility), conditional on stock market participation. The most straightforward channel behind this finding is genetic differences in risk preferences (γ_i) because in a standard asset pricing model (assuming CRRA and Independent and Identically Distributed (IID) returns) $1/\gamma_i$ for individual i is proportional to the share that the individual invests in equities. This interpretation is further confirmed when we study portfolio volatility. The interpretation that a genetic component of preferences for risk-taking in part explains asset allocation decisions in the cross-section of individuals is consistent with recent experimental evidence (e.g., Kuhnen and Chiao, 2009; Cesarini, Dawes, Johannesson, Lichtenstein, and Wallace, 2009a).

Our conclusion about the heritability of risk preferences could be confounded by other determinants of financial risk-taking, in particular wealth and background risk factors that are also heritable, but our results in Table 5 suggest that this is not the case. The genetic component drops only from 32% to 29% when we control for wealth, entrepreneurial activity, health status, and marital status. Our results suggest that risk preferences might play a bigger role than existing empirical evidence suggests. Barsky, Juster, Kimball, and Shapiro (1997) use survey-based measures of investors' risk tolerance and find that while important, they only explain a relatively small fraction of the observed heterogeneity. On the one hand, survey-based measures of risk preferences most likely contain substantial measurement error, possibly explaining the low explanatory power. On the other hand, it is possible that other heritable characteristics, such as the way that investors form expectations, contribute to our findings.

5.3. *Robustness*

5.3.1. *Measurement error*

Our conclusions so far of a significant idiosyncratic environmental factor influencing investment behavior are susceptible to the criticism that measurement error in y is absorbed by e. This may potentially overstate the non-shared component, E, i.e., $\sigma_e^2/(\sigma_a^2+\sigma_c^2+\sigma_e^2)$. As our portfolio data originate from the Swedish Tax Agency and misreporting of security ownership by financial institutions and/or individuals is prosecuted, we consider measurement errors to be infrequent in our data set.[25]

It is also possible that idiosyncratic shocks combined with transaction costs constrain individuals from rebalancing their portfolios to the optimum each year. In Panel A of Table 6, we therefore re-estimate the ACE models for each of the three measures of investment behavior using averages from the time-series rather than measures from 2002. The E component declines when we use time-series averages. Correspondingly, the A component increases by 0.067–0.093 for different investment behaviors when time-series averages are used.

[25] We recognize that some degree of tax evasion is possible among the twins studied in this paper. For securities not to appear in our data, they have to be owned through a foreign financial institution which is not required by law to report information to the Swedish Tax Agency. The individual also has to misreport the ownership, and it has to remain undetected in spite of audits. In addition, financial institutions are required to report large withdrawals from bank accounts around December 31 (only relevant for individuals subject to the wealth tax and who would benefit financially from window-dressing the amounts of their total assets around December 31).

Table 6
Robustness.

Panel A reports results from maximum likelihood estimation of linear random effects models. The model is estimated using data on up to 37,504 Swedish twins. Stock market participant, Share in equities, and Volatility are modeled as linear functions of *Male*, *Age*, *Age-squared*, as well as three random effects representing additive genetic effects, shared environmental effects, and an individual-specific error. We report estimates and standard errors for the fraction of the residual variance attributable to the additive genetic effects (A), the shared environmental effects (C), as well as the individual-specific error term (E). All variables are individual-specific time-series averages, reflecting all data available between 1998 and 2006, conditional on non-missing data for 2002. Panel B reports results from maximum likelihood estimation of linear mixed effects models. Stock market participant, Share in equities, and Volatility are modeled as linear functions of *Male*, *Age*, *Age-squared*, as well as three random effects representing additive genetic effects, dominant genetic effects, and an individual-specific error. We report estimates and standard errors for the fraction of the residual variance attributable to the additive genetic effects (A), the dominant genetic effects (D), as well as the individual-specific error term (E). All data used in Panel B refer to 2002. N provides the number of observations used in each estimation. See Appendix for a detailed definition of all variables.

Panel A: Measurement error Model	N	Variance components		
		A	C	E
Stock market participant	37,504	0.3531	0.0000	0.6469
		0.0099		0.0099
Share in equities	24,396	0.3754	0.0000	0.6246
		0.0116		0.0116
Volatility	10,830	0.4454	0.0290	0.5256
		0.0453	0.0342	0.0177
Panel B: Non-linear genetic effects Model	N	Variance components		
		A	D	E
Stock market participant	37,504	0.2248	0.0754	0.6999
		0.0355	0.0413	0.0124
Share in equities	24,396	0.2313	0.0609	0.7077
		0.0447	0.0512	0.0146
Volatility	10,830	0.3015	0.0787	0.6197
		0.0663	0.0739	0.0195

5.3.2. *Model specification*

The empirical analysis so far has assumed an additive genetic component. However, it is possible that there is a dominant genetic effect as well. This can be thought of as a non-linearity of the genetic effect. When the identical twin correlation is more than twice the fraternal twin correlation, one potential explanation is that a dominant gene influences that behavior. This is the case for some of the correlation comparisons reported in the paper.

A dominant genetic effect can be added in a straightforward way to the model described in Section 3. While a model with A, C, E components and also a D component is not identified with our data, we are able to estimate an ADE model:

$$y_{ij} = \beta_0 + \beta \mathbf{X}_{ij} + a_{ij} + d_{ij} + e_{ij}, \tag{2}$$

where the definitions are similar as previously. The corresponding dominant genetic components is denoted by $\mathbf{d} = (d_{11}, d_{21}, d_{12}, d_{22})'$. Genetics theory suggests the

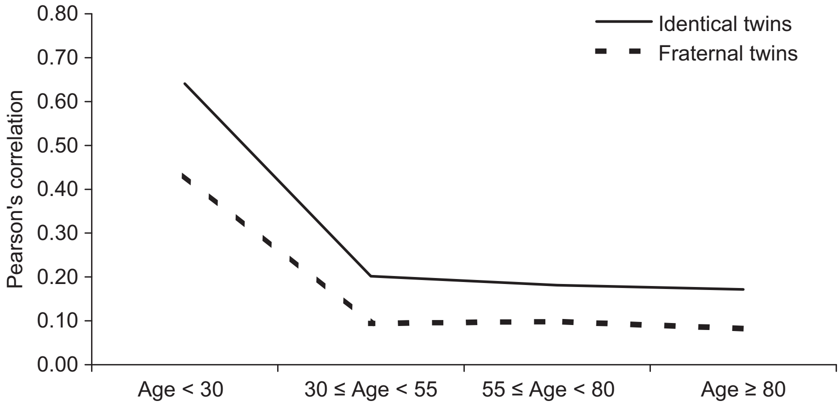

Fig. 2. Pearson's correlations for Share in equities among pairs of identical and fraternal twins across age groups. All data refer to 2002. See Appendix for a detailed definition of all variables.

following covariance matrix:

$$\mathrm{Cov}(\mathbf{d}) = \sigma_d^2 \begin{bmatrix} 1 & 1 & 0 & 0 \\ 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1/4 \\ 0 & 0 & 1/4 & 1 \end{bmatrix}.$$

Panel B of Table 6 shows that D, i.e., $\sigma_d^2/(\sigma_a^2+\sigma_d^2+\sigma_e^2)$, is 0.075, 0.061, and 0.079, respectively, for *Stock market participant*, *Share in equities*, and *Volatility*. However, only one of these estimates is statistically significant at the 10%-level. Given that the C component is zero in all previous model specifications, it is not surprising that the total genetic component (A+D) in the table approximates the previously estimated A component. That is, our conclusions regarding the importance of a genetic component of financial behavior do not change when modeling a non-linear genetic effect.

6. Further evidence and extensions

In this section, we provide further evidence on the importance of genetic and environmental effects for investment behavior. We focus on *Share in equities* as our measure of investment behavior because of the measure's central role in the empirical portfolio choice literature.

6.1. Differences across age groups and gender

We first turn to an analysis of whether the relative importance of genetic and environmental influences on investment behavior vary with age and gender. We start by separately considering the youngest ($Age < 30$) and oldest ($Age \geq 80$) individuals in our sample. We also consider the two in-between groups spanning 25 years each, i.e., 30–54 and 55–79 year-old individuals, respectively.

Fig. 2 reports the correlations among pairs of identical and fraternal twins for asset allocation across age groups. We find that the correlations for identical twins are higher than for fraternal twins regardless of age group. This is not surprising given our previously reported results of a significant genetic component affecting financial behavior. However, we find that both correlations decrease significantly as an individual ages. The decline is particularly pronounced around the age of 30, indicating that this is a particularly defining period for financial behavior during the life-cycle. For the youngest investors, the MZ (DZ) correlation is found to be 0.641 (0.431), compared to 0.172 (0.082) for the oldest investors.

Panel A of Table 7 reports the variance components A, C, and E for different age groups. Fig. 3 illustrates the evidence. The estimates come from separate models for the four age groups. We find that the genetic component decreases by about 63% (from 0.445 to 0.162) when comparing the youngest and the oldest investors. By far, the steepest incremental decline takes place during the early years. During the period before entering the labor market and early on during an individual's life, the genetic component seems to dominate, but as experiences are gained, they start to determine a relatively larger proportion of the variation in financial behavior across individuals.

While the importance of genes is found to decline as a function of age, it is interesting to note that genes are found to matter also for the financial behavior of the oldest individuals in our sample, i.e., those older than 80. As a matter of fact, the A component never attains zero, but remains statistically significant at the 1%-level. The decrease in the importance of the genetic component is significant during early years, but reaches a steady-state level of about 20% already when an individual is in his or her 30's, after which the marginal decline is small. A certain component of an individual's financial behavior never disappears, despite the accumulation of other significant experiences during life.[26]

For those younger than 30 years old, we find that the shared environment component is 0.197, and statistically significant at the 1%-level. That is, about 20% of the

[26] There is evidence of substantial genetic influences on cognitive abilities (e.g., the speed of information processing) in twins 80 or more years old (McClearn, Johansson, Berg, Pedersen, Ahern, Petrill, and Plomin, 1997).

Table 7
Differences across age groups and gender.

The table reports results from maximum likelihood estimation of linear random effects models. The model is estimated using data on up to 37,504 Swedish twins. Share in equities is modeled as a linear function of *Male*, *Age*, *Age-squared*, as well as three random effects representing additive genetic effects, shared environmental effects, and an individual-specific error. We report estimates and standard errors for the fraction of the residual variance attributable to the additive genetic effects (A), the shared environmental effects (C), as well as the individual-specific error term (E). Panel A presents results for different age groups. Panel B reports results for the subset of male and female twin pairs. N provides the number of observations used in each estimation. All data refer to 2002. See Appendix for a detailed definition of all variables.

Model	N	Variance components		
		A	C	E
Panel A: Age groups				
Age < 30	3,390	0.4449	0.1973	0.3578
		0.0617	0.0546	0.0188
30 ≤ Age < 55	9,412	0.1921	0.0000	0.8079
		0.0202		0.0202
55 ≤ Age < 80	10,840	0.1725	0.0100	0.8175
		0.0616	0.0406	0.0268
Age ≥ 80	754	0.1624	0.0000	0.8376
		0.0752		0.0752
Panel B: Gender				
Men	6,812	0.2910	0.0000	0.7090
		0.0205		0.0205
Women	8,602	0.2235	0.0528	0.7237
		0.0564	0.0452	0.0198

cross-sectional variation in investment behavior among the youngest individuals in our sample is explained by the environment which is common to the twins. While the shared environment is not important for investment and financial risk-taking behavior when considering individuals of all ages, it is important for the youngest and least experienced investors. However, this influence of nurture decreases sharply, and disappears completely after the age of 30. This behavior stands in sharp contrast with the finding for the genetic component, which also declines dramatically, but does not attain zero even for the oldest investors. The non-shared environment increases in importance as an individual acquires his own experiences relevant for financial decision-making.

Finally, we turn to gender-based differences in heritability of behavior in the financial domain. Panel B of Table 7 reports the variance components A, C, and E separately for men and women. The number of observations is lower in this analysis as opposite-sex DZ twins are dropped. For men, the A component is 0.291, i.e., somewhat larger than for women for which it is 0.224. The C component is zero for men, but 0.053 for women, though it is not statistically significant. While men and women exhibit significantly different propensities to take on risk in their investment portfolios (men prefer more risk than women), the extent of heritability of these behaviors is similar across men and women.

We conclude that the sources of the heterogeneity in investment and financial risk-taking behavior across individuals vary across age groups. The relative importance of genetic composition and the shared environment is largest for young individuals. Although both components decline in importance as a function of age, the genetic component never disappears completely, not even for those age 80 or older. We also conclude that there is little systematic difference in the heritability of investment behavior between men and women, which suggests that gender differences in investment behavior can be expected to persist.

6.2. Effects of contact intensity

In the domain of investment behavior, there are several ways through which contact and social interaction can impact individuals' behavior. Through word-of-mouth, individuals may learn from each other (e.g., Bikhchandani, Hirshleifer, and Welch, 1992; Shiller, 1995).[27] Individuals may also derive utility from conversations about investments and stock market related events, the way they enjoy discussing restaurant choices in the Becker (1991) model.[28] This has two implications. First, distinguishing between twins that have little contact with one another and those that have lots of contact might allow us to better understand the importance of the environment shared between twins. Secondly, to the extent that identical twins have more contact than do fraternal twins, our estimation procedure could lead to an upward bias in the estimated heritability of financial behavior. In this section, we examine these implications.

We analyze data on twins' contact and meeting intensities from the surveys performed by the Swedish Twin Registry. Specifically, we examine twins' responses to two questions: (i) "How often do you have contact?" and (ii) "How often do you meet?" It is important to note that both the SALT and STAGE surveys were conducted around the same time as we observe the portfolio choice data meaning that responses reflect contemporaneous social interaction.

Table 8 reports results related to twin interactions. Panel A shows summary statistics for contact and meeting frequencies among the twins in our sample.[29] For contact and meeting frequencies, we find statistically significant differences. The mean number of twin pair contacts is 176 per year for identical twins, compared to 77 for fraternal twins. If we instead study the number of times twins meet, then the numbers are 93 per year for identical and 37 for fraternal twins. These differences are statistically significant at the 1%-level.[30] These significant differences in contact intensity emphasize the importance of the analysis we perform in this section.

[27] For an extensive review of this literature, see Bikhchandani, Hirshleifer, and Welch (1998).

[28] Shiller and Pound (1989) report survey data related to information diffusion among stock market investors by word-of-mouth.

[29] These measures are based on the average of what the twins in a pair responded in the surveys. Twins generally have a similar view of the frequency of their contacts. The twin pair correlation between responses for frequency of contact is 0.77.

[30] The correlation between contact and meeting frequencies is 0.64.

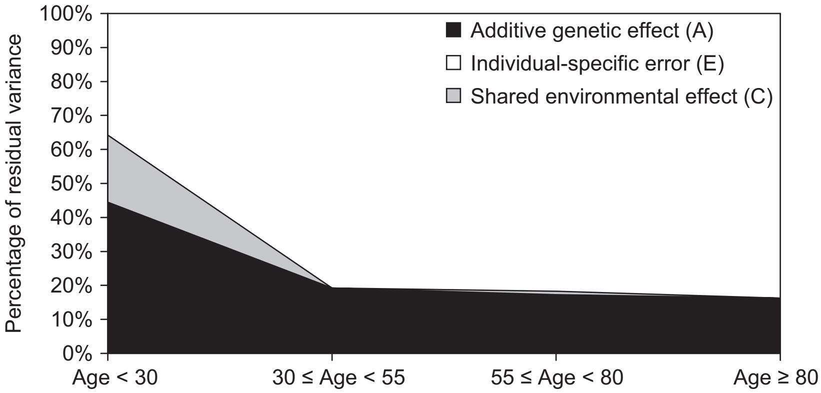

Fig. 3. Residual variance components for Share in equities by age group. Share in equities is modeled as a linear function of *Male*, *Age*, *Age-squared*, as well as three random effects representing additive genetic effects, shared environmental effects, and an individual-specific error. The figure shows estimates for the fraction of the residual variance attributable to the additive genetic effects (*A*), the shared environmental effects (*C*), as well as the individual-specific error term (*E*). All data refer to 2002. See Appendix for a detailed definition of all variables.

Table 8
Effects of twin interaction.

Panel A reports the cross-sectional mean of the number of contacts and meetings between twins for identical and fraternal twins. Panel B reports results from maximum likelihood estimation of linear random effects models. Share in equities is modeled as a linear function of *Male*, *Age*, *Age-squared*, as well as three random effects representing additive genetic effects, shared environmental effects, and an individual-specific error. We report estimates and standard errors for the fraction of the residual variance attributable to the additive genetic effects (*A*), the shared environmental effects (*C*), as well as the individual-specific error term (*E*), separately for twins with little contact (less than 20 contacts per year), intermediate contact (between 20 and 155 contacts per year), and lots of contact (more than 155 contacts per year). *N* provides the number of observations used in each estimation. Data on twin interaction were collected by the Swedish Twin Registry between 1998 and 2006. All other data refer to 2002. See Appendix for a detailed definition of all variables.

Panel A: Summary statistics				
Model	Identical twins		Fraternal twins	
	N	Mean	*N*	Mean
Contacts per year	9,726	176	24,582	77
Meetings per year	9,966	93	24,638	37

Panel B: Contact frequency				
Model	*N*	Variance components		
		A	*C*	*E*
Little contact	5,546	0.1419	0.0000	0.8581
		0.0328		0.0328
Intermediate contact	10,740	0.1347	0.0563	0.8089
		0.0608	0.0403	0.0264
Lots of contact	6,404	0.2382	0.1275	0.6343
		0.0617	0.0518	0.0201

Panel B reports results for different groups of twins based on how often they contact each other. For twins with little contact (less than 20 contacts per year, the 20th percentile), the genetic component (*A*) is 0.142, and statistically significant at the 1%-level. The shared and non-shared environmental components are zero and 0.858, respectively. Interestingly, twins who respond that they do not interact at all or who interact very little still share a significant component when it comes to financial decision-making, and this similarity is found to be caused by shared genes as opposed to a common environment. For twins who have lots of contact (more than 155 contacts per year, the 80th percentile), we find an *A* component of 0.238 and a *C* component of 0.128 which is statistically significant at the 1%-level. The *E* component is 0.634. That is, the social interaction appears to create a common environment that is causing similarity in terms of investment behavior.

Fig. 4 shows the estimated variance components for the three groups based on contact frequency. As can be seen in the figure, the shared environment component increases dramatically when we compare twins with little contact to those who have a lot of contact. The point estimates for the genetic component are similar for the low and intermediate contact frequency groups, but somewhat higher for the high contact frequency group. While Panel B of Table 8 reveals larger standard errors for these results than for those based on the whole data set, it is possible that a lot of contact between twins reinforces genetic similarity. The shared environment component increases dramatically if we compare twins with little contact to those who have a lot of contact. Turning to twin correlations, Fig. 5 shows that twin pairs who interact more also have more similar asset allocations. The MZ (DZ) twin pair correlations are 0.187 (0.075) among twins with little contact. In contrast, the correlations are 0.377 (0.270) for identical (fraternal) twins with lots of contact.

The analysis of contact intensity results in two important conclusions. First, contact intensity and information sharing related to specific investments does not explain the genetic component of financial behavior. A significant genetic factor explains similarity in investment and financial risk-taking behavior even when we study those who have little contact. The evidence that twins who have little contact still display similar financial behavior, emphasizes our conclusion that individuals are biologically predisposed to certain behaviors in the financial domain.

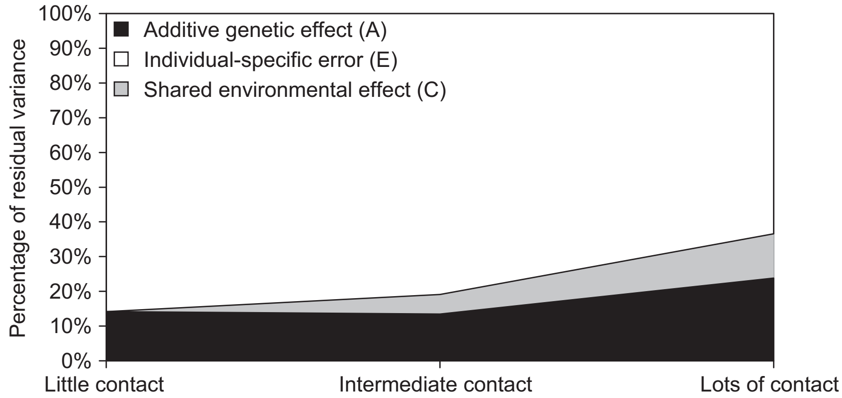

Fig. 4. Residual variance components for Share in equities by contact intensity among twins. Share in equities is modeled as a linear function of *Male*, *Age*, *Age-squared*, as well as three random effects representing additive genetic effects, shared environmental effects, and an individual-specific error. The figure shows estimates for the fraction of the residual variance attributable to the additive genetic effects (*A*), the shared environmental effects (*C*), as well as the individual-specific error term (*E*). All data refer to 2002. See Appendix for a detailed definition of all variables.

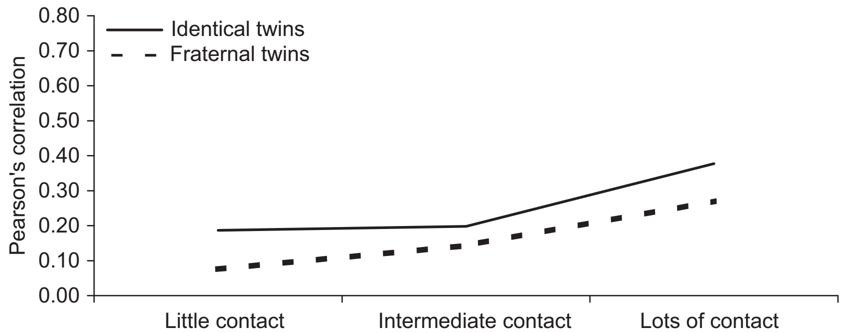

Fig. 5. Pearson's correlations for Share in equities among pairs of identical and fraternal twins by contact intensity. All data refer to 2002. See Appendix for a detailed definition of all variables.

Table 9
Evidence from twins reared apart.

The table reports results from maximum likelihood estimation of linear random effects models. Share in equities is modeled as a linear function of *Male*, *Age*, *Age-squared*, as well as three random effects representing additive genetic effects, shared environmental effects, and an individual-specific error. Differently from above, Share in equities takes on zero for investors that do not participate in the stock market. We report estimates and standard errors for the fraction of the residual variance attributable to the additive genetic effects (*A*), the shared environmental effects (*C*), as well as the individual-specific error term (*E*), separately for twins reared apart (separated at age 5 or earlier) and reared together. All variables are individual-specific time-series averages, reflecting all data available between 1998 and 2006. *N* provides the number of observations used in each estimation. See Appendix for a detailed definition of all variables.

Model	*N*	Variance components		
		A	*C*	*E*
Reared apart	252	0.3848	0.0000	0.6152
		0.1445		0.1445
Reared together	24,372	0.2619	0.0497	0.6884
		0.0372	0.0253	0.0159

Second, individuals who have lots of contact create their own shared environment, which in our formal statistical analysis is captured by the *C* component. For those with little contact, the shared environment can be thought of as their common parenting and family environment when growing up, but those with frequent contact create a common environment as they stay in contact even after separating from their parents. Although not as important as the genetic component, our results do indicate that information diffusion among individuals is a significant explanation for heterogeneity in investor behavior among those with very frequent contact. This finding is related to Hong, Kubik, and Stein (2004) who show that social investors are more likely to invest in the stock market relative to non-social investors. Differently from Hong, Kubik, and Stein (2004), we are able to compare the portfolios of two individuals as a function of twin-pair-specific contact intensity.

6.3. Evidence from twins reared apart

If parents treat identical twins more similarly than they treat fraternal twins, then the genetic component (*A*) and the shared environmental component (*C*) may be confounded, i.e., the estimate of *A* reported so far may be upward biased. In an attempt to remedy such concerns and separate the two effects, we study twins who were "reared apart," i.e., twins who were separated relatively soon after birth and who therefore were exposed to no, or at least very limited, common family environment (e.g., Bouchard, Lykken, McGue, Segal, and Tellegen, 1990).[31]

Considerations by adoption authorities imply that it is uncommon that twins are separated at or around birth. Still, we are able to identify a small subsample of twins who were reared apart by their responses to the following question in the STR's surveys: (i) "How long did you live in the same home as your twin partner?" This question was only asked in the SALT survey, meaning that these data are only available for twins born 1886–1958. We consider twins who were separated at age five or earlier.[32] We also restrict our sample by including twins that do not meet or contact one another more than once a month. To obtain a sufficiently large number of observations to analyze, we modify our main measure of investment behavior, *Share in equities*, to be zero for individuals who do not participate in the stock market, and we identify all twins in the panel, and employ time-series averages across all years that we have data for a given pair of twins. Our final sample of reared-apart twins consists of 20 identical and 232 fraternal twins. For comparison, we also select all twins that lived in the same household until at least age 18, thereby having been subject to the same family environment for a long period.

Table 9 reports separate model estimates for twins reared apart and reared together. Because of the small sample size for twins Reared Apart, we note that the estimates of the variance components are very noisy, but the point estimate for A is large (0.3848) and statistically significant. Not surprisingly, we find that the C component is estimated to be zero. For twins reared together, we find a smaller, more precise point estimate for the genetic component A (0.2619). Interestingly, we also find a weakly significant common component C (0.0497), possibly due to the long period that these twins were reared together. However, even for these twins, the C component is small.

The evidence from twins reared apart provides additional support for the conclusion that there is a significant genetic factor which in part explains cross-sectional heterogeneity in investment behavior. Even twins who were reared apart share a substantial component of their investment behavior.

7. Discussion

What are the implications of our evidence that investment behavior has a significant genetic component? A research agenda in financial economics based in part on genetics has important implications for research on individual investor behavior and for the effectiveness of public policy in the investment domain (Bernheim, 2009).

With respect to stock market participation, our evidence suggests that the fundamental determinants of effective participation costs and the ability to overcome entry barriers are partly genetically determined. To understand the implications, we can focus on a pair i of identical twins (j=1,2) that grew up in the same household. If the outcome y_{ij} is linear in observable fixed effects and the unobservable genetic and shared environmental effects, a_i and c_i, we can eliminate genetic or shared environmental effects by considering the difference between the twins[33]:

$$y_{ij} = \beta_0 + \beta \mathbf{X}_{ij} + a_i + c_i + e_{ij}, \tag{3}$$

$$y_{i1} - y_{i2} = \beta(\mathbf{X}_{i1} - \mathbf{X}_{i2}) + e_{i1} - e_{i2}. \tag{4}$$

Table 10 reports coefficient estimates for a linear probability model for stock market participation, estimated using 2002 data for all 9,710 identical twins.[34] Column 1 reports results when the model is estimated in levels. Column 2 reports results for the twin difference model and involves 4,855 pairs of identical twins. Comparing the estimates in these columns, we find that

Table 10
Stock market participation: eliminating genetic and shared environmental effects.

The table reports results from a linear regression model of stock market participation. The model is estimated for 9,710 identical twins. In column 1, estimation is performed in levels, in column 2 the estimation is performed on differences between identical twins. We also report coefficient estimates and standard errors. N provides the number of observations used in each estimation. All data refer to 2002. See Appendix for a detailed definition of all variables.

	1	2
Intercept	0.8510	0.0020
	0.0438	0.0066
Male	0.0041	
	0.0081	
Age (divided by 100)	−0.5207	
	0.1983	
Age-squared (divided by 1,000)	0.0552	
	0.0228	
Education level 2	0.0401	0.0178
	0.0118	0.0198
Education level 3	0.0839	0.0488
	0.0127	0.0248
Net worth (in million SEK)	0.0212	0.0102
	0.0027	0.0039
Business owner	−0.0387	−0.0170
	0.0261	0.0396
Home owner	0.0329	0.0282
	0.0091	0.0124
Retired	−0.0252	0.0167
	0.0142	0.0214
Poor health	−0.0452	−0.0338
	0.0116	0.0162
Single	−0.0053	−0.0109
	0.0102	0.0142
Family size	0.0017	−0.0018
	0.0035	0.0061
N	9,710	4,855
R^2	0.0195	0.0153

[31] Note that twins who were reared apart were excluded from the analysis reported so far in the paper.

[32] Researchers in behavioral genetics who study twins reared apart also commonly consider twins who were separated a few years and up to a decade after their births (e.g., Finkel, Pedersen, Plomin, and McClearn, 1998).

[33] See Taubman (1976) for an early application of this empirical methodology, and see also Calvet and Sodini (2009).

[34] The cross-sectional variance of the differenced variables is very similar to the variance of the variables in levels.

the effect of a college degree (*Education level* 2) drops from 4.0% to 1.8%, and becomes statistically insignificant, and the effect of a graduate degree (*Education level* 3) drops from 8.4% to 4.9%, but remains statistically significant. That is, controlling for a genetic factor, we conclude that the effect of education on participation in the stock market is significantly lower than we would otherwise have concluded. Similar conclusions apply to other determinants of stock market participation. From a public policy perspective, this result suggests that effects on stock market participation estimated without explicitly modeling a genetic component should be interpreted very cautiously. For example, we find that education is important for stock market participation, but it is mainly the genetic factor of education that is important, so we should not expect policy-driven education to necessarily increase stock market participation rates in the economy.

We want to emphasize that our evidence does not imply that public policy and financial literacy education in the investment domain is necessarily ineffective.[35] Even if variation in participation in the stock market is entirely due to genetic variation, policy initiatives that reduce entry barriers can increase the average participation in the economy. For example, assume that entry barriers are such that only individuals with an IQ above a certain level participate, and assume also that variation in IQ is determined entirely by genetic variation. In this case, variation in stock market participation is entirely due to genetic differences. If public policy reduces the entry barriers such that a lower level of IQ is sufficient for participation, the average participation would increase in the economy while the heterogeneity in stock market participation would still be entirely due to genes. By contrast, changing any of the explanatory variables in a model for stock market participation by way of public policy is only effective to the extent that they have a non-genetic influence on the participation decision. So our evidence also has implications for the design of policy.

The implications of our evidence with respect to asset allocation decisions are different and it is more difficult to see concrete public policy implications in this case. A substantial genetic preference component implies that cross-sectional heterogeneity in risk-taking preferences arises naturally in an economy. It also implies that risk-taking should be similar between children and their parents. To the extent that economic outcomes reflect compensation for risk-taking, this result also implies that genetic similarity is a potentially important and (differently from parenting and the shared household environment) lasting channel for intergenerational similarities in portfolio choices (Chiteji and Stafford, 1999, 2000) and wealth (Charles and Hurst, 2003).

Furthermore, our evidence of a genetic component of risk preferences has important implications for a growing body of economics research that employs evolutionary models to explain certain preferences or behavior in the population of an economy (e.g., Robson, 2001a; Robson and Samuelson, 2007; Levy, 2005; Netzer, 2009). For example, Brennan and Lo (2009) propose a model in which heterogeneity in risk aversion, anomalies, and other investment behaviors emerges as a result of evolutionary forces. Importantly, their model can explain the coexistence of individually rational investment behavior along with behavioral biases in an economy. This and other evolutionary models in economics assume that preferences are at least partly, and often entirely, heritable. The evidence reported in this paper offers empirical support for such assumptions.

Finally, it is important to address the fact that our evidence comes from Swedish data.[36] Sweden is often perceived as more homogeneous than, e.g., the U.S. Stock market participation is indeed higher in Sweden (76% in our data) than in the U.S. ($\approx 50\%$).[37] As we discuss above, the importance of genetic, shared, and individual-specific environmental factors depends on the exact nature of stock market participation costs that individuals face. While we do not have any reason to believe that such entry barriers are fundamentally different in Sweden compared to, e.g., the U.S., we recognize the possibility that differences exist and that they affect our results. This concern should be of less importance for our evidence on asset allocation as these results are conditional on stock market participation and most likely reveal variation in underlying risk preferences. While we cannot compare the genetic variation of asset allocation between the U.S. and Sweden, we point out that the total variation in the *Share in equities* (conditional on stock market participation) appears to be quite similar for both countries. Using PSID data for the U.S., Kullmann and Siegel (2005) report a standard deviation of 0.30 for the share in equities, while we find the standard deviation in our Swedish data set to be 0.34. This suggests that even though Sweden is often perceived as more homogeneous than the U.S., this does not seem to be the case with respect to asset allocation choices made by individual stock market participants.

8. Conclusions

In this paper, we study the fundamental determinants of individual investor behavior. In particular, we examine two important financial decisions that most individual

[35] Van Rooij, Lusardi, and Alessie (2007) report that those who have low financial literacy are significantly less likely to invest in stocks, suggesting that increased literacy in the investment domain results in increased stock market participation. Bernheim and Garrett (2003) find that those who grew up in a state with a high school financial curriculum mandate have 1.5% higher savings rates compared to others in their birth cohort, and Bernheim, Garrett, and Maki (2001) find similar effects of employer-based retirement education plans.

[36] We examined the possibility of using data from a U.S. twin registry. The largest is the Mid-Atlantic Twin Registry (MATR) at the Virginia Commonwealth University with more than 37,000 twins of all ages who were born in or live in North Carolina, South Carolina, and Virginia. Other large U.S. twin registries used in twin research include the Minnesota Twin Family Study (MTFS) and the University of Washington Twin Registry. The problem with using these twin registries is that data on twins' individual portfolio choices are not available. We believe that Sweden is the only country where such a matching is currently feasible.

[37] See, e.g., Bucks, Kennickell, Mach, and Moore (2009) for U.S. data on stock market participation.

investors in developed countries face: the decision to invest in the stock market and the choice of asset allocation. We analyzed data on 37,504 twins to decompose the variance of these decisions into an unobservable genetic component and environmental components that are either common (shared) or non-shared among twins.

We find that a genetic factor is able to explain a significant proportion of the variation across individuals. Specifically, about a third of the cross-sectional variance in the examined investment decisions is explained by genetic differences. The magnitude of such a genetic factor is very large compared to other individual characteristics, such as age, gender, education, and wealth, which have been analyzed in the existing finance literature. We find that the genetic factor explains a larger proportion of the variation across individuals than do these individual characteristics combined. Overall, our evidence indicates that an individual's genetic composition is an important determinant of the individual's investment behavior.

While our evidence implies that nature is an important determinant of an individual's investment behavior, we also show considerable environmental influences. We find that the non-shared environment tends to be much more important than the shared environment in explaining the cross-sectional variance in investment behaviors. The family environment, i.e., nurture, does have a significant effect on the investment behavior of young individuals, but this effect is not long-lasting (unless the twins stay in frequent contact) as we find that it disappears when an individual gains his/her own experiences.

Appendix A. Definition of all variables

Variable	Description
Types of twins	
Identical twins	Twins that are genetically identical, also called monozygotic twins. Zygosity is determined by the Swedish Twin Registry based on questions about intrapair similarities in childhood.
Fraternal twins	Twins that share on average 50% of their genes, also called dizygotic or fraternal twins. Fraternal twins can be of the same sex or of opposite sex. Zygosity is determined by the Swedish Twin Registry based on questions about intrapair similarities in childhood.
Reared apart twins	A pair of twins that were separated at age 10 or earlier. The data are obtained from the Swedish Twin Registry.
Reared together twins	A pair of twins that were not separated at age five or earlier. The data are obtained from the Swedish Twin Registry.
Measures of investment and financial risk-taking behavior	
Stock market participant	An indicator variable that equals one if an individual has non-zero direct or indirect equity investments and zero otherwise.
Share in equities	The market value of direct and indirect equity investments divided by the market value of all financial assets. This variable is available only for stock market participants and missing for non-stock market participants.
Volatility	The annualized daily volatility of an individual's portfolio of direct and indirect equity holdings. We calculate daily equity portfolio returns using portfolio weights reported by Statistics Sweden as of December 31 for a given year as well as daily asset returns during the subsequent year. We then calculate the annualized daily portfolio volatility for every year. The largest one percentile of volatility estimates is set to missing. This variable is only available for those individuals with positive equity investments for which we have complete return data, it is missing otherwise. Asset return data are obtained from various sources including Datastream, Bloomberg, and Swedish Investment Fund Association.
Sociodemographic characteristics	
Male	An indicator variable that equals one if an individual is male and zero otherwise. Gender is obtained from Statistics Sweden.
Age	An individual's age on December 31 of a given year as reported by Statistics Sweden.
Education level 1	An indicator variable that equals one if an individual has completed less than 10 years of schooling, zero otherwise. Educational information is obtained from Statistics Sweden.
Education level 2	An indicator variable that equals one if an individual has completed high school but not college, zero otherwise. Educational information is obtained from Statistics Sweden.
Education level 3	An indicator variable that equals one if an individual has at least completed college, zero otherwise. Educational information is obtained from Statistics Sweden.
Disposable income	Disposable income of the individual's household as reported by Statistics Sweden in nominal Swedish Krona (SEK) (unless indicated otherwise) for a given year.
Net worth	The difference between the market value of an individual's assets and her liabilities, calculated by Statistics Sweden at the end of each year and expressed in nominal Swedish Krona (SEK) (unless indicated otherwise).
Financial assets	The market value of an individual's financial assets as reported by Statistics Sweden at the end of each year, expressed in nominal Swedish Krona (SEK) (unless indicated otherwise). Financial assets include checking, savings, and money market accounts, (direct and indirect) bond holdings, (direct and indirect) equity holdings, investments in options, and other financial assets such as rights, convertibles, and warrants.
Business owner	An indicator variable that equals one if an individual's income from active business activity is more than 50% of the individual's labor income and zero otherwise. The comparison is performed using absolute values of income. Income data are obtained from Statistics Sweden.
Home owner	An indicator variable that equals one if the market value of owner-occupied real estate is positive and zero otherwise. Market values are obtained from Statistics Sweden.
Retired	An indicator variable that equals one if an individual receives retirement income and zero otherwise. Retirement income data are from Statistics Sweden.
Poor health	An indicator variable that equals one if an individual receives payments due to illness, injury, or disability and zero otherwise. Payment data are from Statistics Sweden.

Single	An indicator variable that equals one if an individual is neither married nor in a registered partnership and zero otherwise. The data on civil status are from Statistics Sweden.
Family size	The total number of people in a household. The data are from Statistics Sweden.
Other	
Contacts per Year	The number of contacts per year between twins. The number is calculated as the average of the numbers reported by both twins. If only one twin provides a number, this number is used. The data are obtained from the Swedish Twin Registry.
Meetings per year	The number of meetings per year between twins. The number is calculated as the average of the numbers reported by both twins. If only one twin provides a number, this number is used. The data are obtained from the Swedish Twin Registry.

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