The Fetal Origins Hypothesis in Finance: Prenatal Environment, the Gender Gap, and Investor Behavior

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We find that differences in individuals' prenatal environments explain heterogeneity in financial decisions later in life. An exogenous increase in exposure to prenatal testosterone is associated with the masculinization of financial behavior, specifically with elevated risk taking and trading in adulthood. We also examine birth weight. Those with higher birth weight are more likely to participate in the stock market, whereas those with lower birth weight tend to prefer portfolios with higher volatility and skewness, consistent with compensatory behavior. Our results contribute to the understanding of how the prenatal environment shapes an individual's behavior in financial markets later in life. (*JEL* G02)

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A large body of literature in economics shows the importance of the early life environment for economic outcomes much later in life. In fact, several "fetal origins" studies have shown that conditions and circumstances before birth are of first-order importance when it comes to explaining the observed heterogeneity in individuals' life trajectories, in particular their long-term human and health capital. In their review article, Almond and Currie (2011b) go as far as asking, "[W]hat if the nine months *in utero* are one of the most critical periods in a person's life [...]?"

In financial economics research, specifically related to individual investor behavior, the importance of the early life environment has received limited attention. Some studies, which focus on the *postnatal* environment, have attempted to fill this void. For example, the evidence reported by Malmendier and Nagel (2011) suggests that "Depression Babies" develop more aversion to financial risk taking later in life. Chetty, Friedman, Hilger, Saez, Schanzenbach, and Yagan (2011) report that the preschool (kindergarten) environment explains some asset allocation decisions among adults, such as contributing to a 401(k) retirement savings plan and owning a home.[1] Cronqvist, Siegel, and Yu (2015) show that individuals who grew up during the depression era, or in relatively less wealthy families, develop a more value-oriented investment style.

In this study, we extend these efforts by examining whether differences in the *prenatal* (i.e., prebirth) environment explain heterogeneity in the investment behavior of adults, in particular with respect to financial risk taking. First, we examine the long-term effects of differential prenatal exposures to testosterone. We focus on testosterone as it is the most potent steroid (sex) hormone in humans and is critical for the development of the male fetus, including the masculinization of the brain. Existing research on the effect of prenatal testosterone on risk taking has generally relied on the 2D:4D finger ratio (i.e., the ratio of the index and ring finger lengths). A noisy biomarker of prebirth testosterone exposure, it has provided inconclusive evidence (e.g., Apicella *et al.* 2008; Sapienza, Zingales, and Maestripieri 2009). Our empirical identification strategy instead relies on a natural experiment that occurs in some twin pregnancies. More specifically, the "Twin Testosterone Transfer" (TTT) hypothesis postulates that, in the case of opposite sex twins, the higher level of prenatal testosterone in the amniotic fluid contributed by the male fetus increases the prebirth testosterone exposure of the female fetus sharing the womb with the male fetus and results in a masculinization of the female fetus, including the brain.

Second, we study the long-term effects of differences in birth weights. Although the limitations of birth weight as a summary measure of endowments at birth is increasingly well recognized (e.g., Almond, Chay, and Lee 2005), little progress has been made toward identifying a superior measure. We

1 Several studies have also found that experiences in adulthood are important for an individual's investment behavior later in life (e.g., Malmendier and Nagel 2014; Knüpfer, Rantapuska, and Sarvimäki 2014).

use a sample of identical twins to control for confounding factors, such as unobserved characteristics of the mother as well as the genetic makeup of the twins. This approach ensures that the birth-weight differences are driven by environmental factors (e.g., nutritional intake within the uterus), rather than by genetic factors.

The data we use for this study come from the Swedish Twin Registry (STR), the world's largest twin registry, with very detailed information on same- and opposite-sex twin pairs from birth cohorts dating back to the 19th century, and they constitute a combination of register and survey data. These data have been matched with detailed financial data from the Swedish Tax Authority and other individual data (e.g., family structure and education data) from Statistics Sweden, and they allow us to measure individuals' financial decisions over several years.

Our evidence is consistent with the fetal origins hypothesis, and it suggests that the prenatal environment is important for an individual's financial decisions decades later in life. First, we find that a female with a male co-twin (i.e., an individual in the treatment group) takes significantly more risk later in life compared with a female with a dizygotic female co-twin (i.e., an individual in the control group). A treated female's allocation to risky assets is about 3% higher than the average allocation of a female in the control group is. Similarly, in comparison with the control group, her portfolio exhibits a 3% higher volatility and a 14% higher allocation to individual stocks relative to mutual funds. These effects also offer an important insight into the nature of the gender gap in financial risk taking (e.g., Croson and Gneezy 2009; Sundén and Surette 1998).[2] Specifically, we find that a significant proportion, between 10% and 39%, of the gender gap in our data is explained by increased prebirth exposure to testosterone, suggesting that biological factors explain a sizable proportion of the gender gap. Consistent with the masculinizing effect of prenatal testosterone, females with male co-twins also trade more and invest more in lottery-type assets, as expected given the previously documented gender differences for both outcomes (e.g., Barber and Odean 2001; Kumar 2009). Finally, to address concerns about confounding social effects owing to the presence of a male co-twin, we verify that intra-twin pair social interactions in adulthood do not explain our results. Importantly, we find no evidence that females who are raised with a male sibling, but who do not share the womb with a male co-twin, display any masculinization of their financial behavior.

Second, controlling for twin pair fixed effects, we find that those with lower birth weight (i.e., with more adverse prenatal conditions in a general sense) are less likely to hold risky assets. However, conditional on holding risky assets, they prefer more volatile equity portfolios and hold relatively more individual

2 We recognize that the label should be *sex gap*. We nevertheless follow the convention and describe the differences between behavior of men and women as *gender gap*.

stocks than those with higher birth weight do. A one standard-deviation decrease in *Birth Weight (ln)* increases the volatility of the portfolio by about 5%, and the proportion of directly held stocks by about 10% relative to respective means for the entire sample. These outcomes are consistent with generally better financial decisions of those with higher birth weight, as expected given the existing evidence of a positive relationship between birth weight and cognitive abilities (Black, Devereux, and Salvanes 2007). The outcomes are also consistent with compensatory behavior (e.g., "gambling for resurrection") by those with inferior starting conditions, as reflected by low birth weight. Indeed, we find that low-birth-weight investors hold portfolios that have significantly higher skewness.

Finally, to distinguish between prenatal conditions affecting financial decisions directly through preferences or indirectly through the ability to make good decisions, we perform a mediation analysis. We find that prenatal testosterone has a direct effect on the share of risky assets and birth weight has a direct effect on portfolio skewness. For volatility, however, both prenatal treatments operate indirectly. Thus, the prenatal environment affects financial decisions by shaping investors' preference as well as by working through indirect cognitive channels that affect investors' ability to make good decisions.

Our paper contributes to the preexisting literature in finance and economics research. First, this study is among the earliest to incorporate the fetal origins hypothesis into financial economics. This hypothesis has been very useful for economists' understanding of the long-term effects of the early environment on health and human capital (e.g., Almond and Currie 2011b; Currie 2011), and we show that it is also useful for understanding the financial decisions that individual investors make later in life. Different from existing studies in economics, we explicitly consider the effects of compensatory behavior by those with lower birth weight, as discussed by studies in medicine and biology (Metcalfe and Monaghan 2001; Hack *et al.* 2002).

Second, with a growing body of literature in finance having established the importance of genetics in explaining cross-sectional heterogeneity in financial risk taking (e.g., Cesarini *et al.* 2009; Barnea, Cronqvist, and Siegel 2010; Cesarini *et al.* 2010), the focus is shifting to a search for the environmental circumstances and life experiences that explain outcomes of interest to financial economists. Our research shows that differences in the early life environment, even prebirth experiences in the womb, can explain subsequent differences in investor behavior.

Finally, our paper contributes to the literature at the intersection of finance and neuroscience that seeks to establish the causal effects of prenatal testosterone exposure, but which to date has provided inconclusive evidence (e.g., Apicella *et al.* 2008; Coates, Gurnell, and Rustichini 2009; Sapienza, Zingales, and Maestripieri 2009). Using a different identification strategy and field data on individuals' financial decisions, our research has the potential to clarify the role that prenatal testosterone exposure plays for financial behavior later in life and to shed light on the determinants of gender differences with respect to these behaviors.

1. Related Research

In this section, we review the science providing the basis for our hypothesis that different prenatal environments might explain heterogeneity in adult investor behavior, in particular, with respect to financial risk taking.

1.1 Fetal origins hypothesis

The fetal origins hypothesis was pioneered in medical research by Barker (1990), who argued that the intrauterine environment may program a fetus to have particular characteristics affecting that individual in adulthood. According to this hypothesis, the effects of prenatal conditions and circumstances may be very persistent. More specifically, Barker argued that individuals who are starved or otherwise experience poor nutrition *in utero* are significantly more likely to become overweight as adults, possibly because of compensatory programming occurring *in utero*, and that these individuals are more likely to suffer from diseases associated with obesity, including diabetes and cardiovascular-related diseases (e.g., Barker 1995). This mechanism is called "fetal programming," and it has just started to be researched and understood in depth. One possible mechanism is that the epigenome, which may be thought of as a set of switches causing parts of the genome to be expressed or not, is affected in a significant way by the prebirth environment (e.g., Petronis 2010).[3] Preexisting scientific evidence related to the fetal origins hypothesis constitutes the basis for the empirical analysis pursued in this study (i.e., financial decisions later in life may in part be the outcome of fetal programming).

Over the past decade, the fetal origins hypothesis has made its way from medical research into economic research. Currie and Hyson (1999) was the first in economics research to conclude that the fetal origin effects were not confined to long-term health capital but also applied to human capital measures (e.g., IQ and educational attainment). Studies in applied economics have used exogenous variation in factors, such as nutrition, diseases, and pollution, to identify potential causal treatment effects of the prenatal environment.

To provide only a few examples from applied economics research, the long-term effects of poor nutrition *in utero* have been studied using data from the *Hongerwinter* of 1944–45. Toward the end of World War II, Germany effectively stopped all food supply to the Netherlands, and adult rations dropped to as low as 580 kilocalories per day. Significant effects on disease rates later in

[3] See, e.g., Lombardo *et al.* (2012a) and Lombardo *et al.* (2012b) for scientific papers related to fetal programming.

life have been reported (e.g., Stein, Susser, and Saenger 1975; Ravelli, Stein, and f 1976). Other studies of the long-term effects of prenatal nutrition on health and human capital include studies of the *Phylloxera* insect, which asymmetrically affected available income and food resources at different vineyards in France in the late 19th century (e.g., Banerjee *et al.* 2010), and studies of fasting during the Ramadan among pregnant mothers (e.g., Almond and Mazumder 2011).

Focusing on the health of the mother, Almond, Chay, and Lee (2005) and Almond (2006) study children of mothers who were pregnant during the influenza epidemic of 1918 in the United States. They find that the children experienced reduced educational attainment, lower income and socioeconomic status, and accelerated disability rates as adults. Some of these differences remain observable in the "treated" individuals even when they were in their 80s. Others have studied the long-term treatment effects on cognitive ability of prebirth exposure to pollution, such as exposure to Chernobyl fallout in Sweden (e.g., Almond, Edlund, and Palme 2009) and the effects of particulate matter (PM) in the air on educational attainment (e.g., Sanders 2012).

The general conclusion from this literature is the importance of the prenatal environment for long-term health and human capital.[4]

1.2 Twin testosterone transfer hypothesis

Given the importance of risk in financial decisions and the well-documented gender difference in risk taking, we examine the long-term effects of heterogeneous *prenatal* exposure to testosterone. Testosterone is one of the most potent hormones in humans and one that has consistently been found to be related to risk taking among adults. During gestation (i.e., while in the mother's womb), a human fetus endogenously generates testosterone, with the male fetus generating much higher levels compared with the female fetus (e.g., Kuijper *et al.* 2013). Indeed, high levels of prenatal testosterone are necessary for the masculinization of the fetus, and in its absence, female structures develop, even in a genetically male fetus.[5] Prenatal exposure to testosterone has been shown to cause permanent changes in the brain's development, the so-called organizational effects of testosterone, which we study.

In addition to significant differences between male and female fetuses, studies show there is also substantial within-sex variation in prebirth testosterone exposure. For example, Baron-Cohen, Knickmeyer, and Belmonte (2005) report significant cross-sectional variation in prenatal testosterone among both male fetuses (N=41; prenatal T range in nmol/l is 0.125-1.800,

[4] We refer to Almond and Currie (2011a) and Almond and Currie (2011b) for additional references and a more complete and in-depth review of the fetal origins hypothesis.

[5] The default sex among mammals is female. With birds, for example, the default sex is male, and the development of the female sex depends on the exposure to ovarian hormones, such as estrogen. In mammals feminization through estrogen occurs later than masculinization and largely outside of the womb (Baron-Cohen, Lutchmaya, and Knickmeyer 2004).

with a mean of 0.943 and a standard deviation of 0.365) and female fetuses (N=30; prenatal T range in nmol/l is 0.150-0.800, with a mean of 0.358 and a standard deviation of 0.161). Thus, variation in prenatal testosterone exposure is a promising approach to study the effects of different prebirth environments on financial risk taking, as well as other financial behaviors for which men and women have been shown to differ.

Any study of prenatal testosterone is associated with several empirical challenges. First, the direct measurement of prenatal testosterone in the amniotic fluid in pregnant mothers (via amniocentesis) is invasive and has therefore been restricted to small and potentially non-representative samples (e.g., van de Beek *et al.* 2004; Baron-Cohen, Lutchmaya, and Knickmeyer 2004). Second, exogenous manipulation of testosterone is increasingly used as a treatment effect in research at the intersection of economics, finance, and neuroscience (e.g., Eisenegger *et al.* 2009; Zak *et al.* 2009). However such manipulation during human pregnancy is ethically precluded. Finally, exogenous prenatal testosterone manipulation would be impractical for our study because it would take several decades to conduct the treatment and then observe the effect on financial decisions later in life.

Existing research on the effect of prenatal testosterone relevant to finance has employed the 2D:4D finger ratio (i.e., the ratio of the index and ring finger lengths). It is a noisy biomarker for prenatal testosterone exposure and has produced inconclusive results. Apicella, Dreber, Campbell, Gray, Hoffman, and Little (2008) and Sapienza, Zingales, and Maestripieri (2009) find no statistically significant relation between 2D:4D ratio and financial risk taking. Coates, Gurnell, and Rustichini (2009) find that the 2D:4D ratio is related to the profitability of 44 professional traders at the London Stock Exchange, even though it is possible that this result reflects a cognitive ability effect, as opposed to a risk-taking effect (e.g., Coates and Herbert 2008).

The identification strategy in this study relies on a natural experiment that occurs with some twin births, and is referred to as the "Twin Testosterone Transfer" (TTT) hypothesis. Testosterone transfer from male fetuses to neighboring fetuses via diffusion across fetal membranes was first confirmed in animals (e.g., vom Saal and Bronson 1980; Hauser and Gandelman 1983).[6] Several studies of humans have reported evidence consistent with the TTT hypothesis, both with respect to elevated testosterone levels, as well as the masculinization of anatomical, physiological, and—to some extent—behavioral traits caused by the presence of a male fetus in the womb (Slutske *et al.* 2011; Heil *et al.* 2011; Miller and Halpern 2014). Tapp, Maybery, and Whitehouse (2011) conducted a comprehensive review of TTT research

6 Consistent with the TTT, researchers have documented that the intra-uterine position (IUP) is important (e.g., Ryan and Vandenbergh 2002). In other words, for animals for which multiple births are common (e.g., mice), female fetuses developing in between two males in the womb show significantly more masculinized traits later in life.

and concluded that "while uneven, the evidence for the TTT hypothesis is sufficient to warrant further investigation, ideally using large samples of same- and opposite-sex twins, along with control groups of same- and opposite-sex siblings when the characteristics assessed are potentially open to social influences."

This study employs the approach recommended by Tapp, Maybery, and Whitehouse (2011) to investigate financial decisions, in particular, financial risk taking. It is among the first applications of the TTT hypothesis to economics (see also Gielen, Holmes, and Myers 2016).

1.3 Birth weight

A large amount of literature in economics documents birth weight as a predictor of long-term outcomes for adults. More specifically, differences in birth weight are related to differences in health and human capital, much later in life. Birth weight is the most widely available and used proxy summary measure of the prenatal environment. Some researchers have emphasized that birth weight does not fully capture fetal origins effects because shocks in the first trimester of the pregnancy have been found to be especially critical, whereas the fetus gains most of its weight in the third trimester (e.g., Almond, Chay, and Lee 2005). Consequently, birth weight may not constitute a representative measure of circumstances during the most critical period of the development of a human fetus. Because little progress has been made toward identifying an alternative, superior summary measure, birth weight remains an important measure in economic research on the effects of the prenatal environment.

Several studies have used cross-sectional data to show that low birth weight is related to long-term economic outcomes, such as educational attainment, employment, and earnings (e.g., Currie and Hyson 1999).

To control for difficult-to-measure socioeconomic and genetic variables, more recent studies have used within-sibling or within-twin variation to identify the effects of birth weight and confirmed the previous results (e.g., Behrman and Rosenzweig 2004; Almond, Chay, and Lee 2005).[7]

Birth weight may be directly or indirectly related to financial decisions later in life. First, fetal programming may directly affect preferences. Those with higher birth weight (i.e., better endowments at birth in a general sense) may be expected to take more risk. However, from an evolutionary perspective in which maximizing the propagation of an individual's genes is important (e.g., Robson 2001a,b), individuals with lower birth weight may have been programmed to compensate for lagging behind at birth; for example, by investing in portfolios with high volatility or high skewness (e.g., Metcalfe and Monaghan 2001; Hack *et al.* 2002). Second, there may be an indirect effect on financial decisions because birth weight has been found to be related to socioeconomic outcomes,

[7] We also refer to Currie (2009), Almond and Currie (2011a), and Currie (2011) for a more detailed review of the evidence related to birth weight, and health and human capital later in life.

including education, IQ, and earnings (e.g., Behrman and Rosenzweig 2004; Black, Devereux, and Salvanes 2007), which may correlate with individuals' financial behavior, including their willingness to take risk.

2. Data

2.1 Data sources and summary statistics

Our data come from the Swedish Twin Registry (STR). The world's largest twin registry, it constitutes a combination of registry and survey data. Specifically, we obtained data from the "Screening Across Lifespan Twin" (SALT) database and the "Swedish Twin Studies of Adults: Genes and Environment" (STAGE) database. Overall, they provide very detailed information on over 40,000 same- and opposite-sex twin pairs with known zygosity from birth cohorts dating back to the 19th century. For the period 1999–2007, we also obtained for each twin detailed financial data from the Swedish Tax Authority and demographic information from Statistics Sweden (e.g., family structure and education). Last, our data set contains the number of securities owned at the end of the year and security-level data that we have collected from Bloomberg, Datastream, Morningstar, SIX Telekurs, Standard & Poor's, and the Swedish Investment Fund Association. We select twins that in a given year are at least 18 years old and have positive disposable income and net worth.

For our analysis of prenatal testosterone, we further select all fraternal (i.e., dizygotic) twins. In the main analyses, we compare fraternal female twins with a male co-twin (i.e., those of opposite-sex twin pairs) to fraternal female twins with a female co-twin (i.e., those of same-sex twin pairs). In some specifications, we also include fraternal male twins to measure gender differences in risk taking. Our final sample consists of 34,460 fraternal twins: 9,410 female twins of opposite-sex pairs (F_M), 9,093 female twins of same-sex pairs (F_F), and 15,957 male fraternal twins.[8] In Table 1, Panel A, we report summary statistics of selected sociodemographic characteristics, pooled across all 9 years, but separately for women with female co-twins (F_F), women with male co-twins (F_M), and men. We provide a detailed definition of all variables in Table A1. The mean age for women is 57 and for men it is 56, suggesting that the twins in our data set were born, on average, in the 1940s. (F_F) twins and (F_M) twins differ with respect to the number of siblings that they have (excluding their co-twin) and in their birth order. Same-sex female twins are slightly more likely to be first-borns than are opposite-sex or same-sex male twins. In our empirical analyses, we therefore control for differences in age and in family structure.

Several economic outcomes, such as business ownership, disposable income, and net worth, exhibit a clear gender difference. The difference between the

[8] In our sample, the ratio of females of same-sex twin pairs to females of opposite sex twin pairs is 0.966. According to the 2012 World Development Report, in Sweden, the probabilities of male and female birth (respectively, 0.5146 and 0.4854) imply a ratio of 0.943 ($=0.4854^2 \times 0.4854 \times 0.5146$).

Table 1
Summary statistics: Socioeconomic characteristics

Panel A: Twin testosterone transfer sample (fraternal twins)

	Female with female co-twin (F_F) ($N=61,099$)		Female with male co-twin (F_M) ($N=63,042$)		Male ($N=106,975$)	
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
Age	57.399	15.770	56.724	13.862	55.941	14.129
Birth order	1.599	1.275	1.679	1.430	1.688	1.422
Number of siblings	1.150	1.385	1.274	1.518	1.309	1.500
Net worth (ln)	12.619	1.520	12.664	1.518	13.001	1.459
Volatility of labor income	14.089	13.646	13.603	13.075	13.473	13.596
Business owner	0.014	0.119	0.016	0.126	0.034	0.181
Years of education	9.368	4.957	10.070	4.451	9.741	4.392
Missing education data	0.162	0.369	0.103	0.304	0.109	0.311
Poor health	0.174	0.379	0.204	0.403	0.126	0.332
Single	0.210	0.407	0.207	0.405	0.267	0.442
Divorced	0.120	0.324	0.124	0.330	0.103	0.304
Number of children	0.586	1.034	0.592	1.030	0.662	1.076
Retired	0.408	0.491	0.370	0.483	0.354	0.478
Disposable income (ln)	12.268	0.596	12.277	0.586	12.475	0.692
Bias index[1)]	1.894	1.699	1.961	1.747	2.510	1.971

Panel B: Birth weight sample (identical twins)

	Lowest-birth-weight quartile ($N=5,140$)		Highest-birth-weight quartile ($N=2,581$)		Entire sample ($N=17,510$)			
					Observations by twin		Within-twin-pair differences	
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
Birth weight (g)	1,759.7	239.7	3,308.6	210.7	2,413.9	567.0	356.0	320.2
Birth weight (ln)	7.462	0.151	8.102	0.062	7.760	0.246	0.154	0.145
Age	59.354	9.692	56.727	8.800	57.854	9.274	0.000	0.000
Birth order	1.462	0.772	2.071	1.133	1.688	0.964	0.000	0.000
Number of siblings	1.109	1.345	1.506	1.379	1.252	1.340	0.000	0.000
Net worth (ln)	13.019	1.405	13.209	1.416	13.122	1.390	1.143	1.174
Volatility of labor income	0.121	0.111	0.132	0.114	0.119	0.109	0.089	0.112
Business owner	0.024	0.152	0.038	0.190	0.024	0.154	0.037	0.190
Years of education	10.311	4.427	11.070	4.203	10.844	4.279	1.871	2.931
Missing education data	0.094	0.292	0.067	0.251	0.076	0.265	0.045	0.207
Poor health	0.175	0.380	0.199	0.399	0.175	0.380	0.222	0.416
Single	0.117	0.322	0.106	0.308	0.119	0.323	0.132	0.339
Divorced	0.160	0.366	0.149	0.356	0.155	0.362	0.243	0.429
Number of children	0.495	0.895	0.621	0.947	0.579	0.957	0.437	0.769
Retired	0.357	0.479	0.272	0.445	0.312	0.463	0.132	0.339
Disposable income (ln)	12.367	0.633	12.339	0.712	12.357	0.629	0.406	0.572
Bias index[2)]	2.288	1.853	2.302	1.974	2.251	1.913	1.695	1.477

Table 1, Panel A, provides summary statistics for several socioeconomic characteristics for the fraternal twins used in the Twin Testosterone Transfer analyses, separately for women with a female co-twin (F_F), women with a male co-twin (F_M), and for men. Table 1, Panel B, provides summary statistics for the identical twins used in the Birth-weight analyses, separately for the lowest-birth-weight quartile, the highest quartile, and the entire sample. The last two columns of Panel B report summary statistics for within-twin-pair differences. All variables are defined in detail in Table A1. N provides the total number of twin-year observations.
1) The bias index is only available for a subset of 42,010, 44,302, and 80,913 F_F, F_M, and male twins.
2) The bias index is only available for a subset of 11,142 idenditcal twins (with 3,220 in the lowest- and 1,668 in the heighest-birth-weight quartile).

treatment (F_M) and the control group (F_F) of female twins is typically smaller; nonetheless, the values for females of opposite-sex pairs are skewed toward the corresponding values for males.

For our analysis of birth weight, we focus on a subset of twins included in the SALT database for which we have self-reported birth-weight information. We consider only identical (i.e., monozygotic) twins, allowing us to attribute within-pair differences to environmental, as opposed to genetic, differences. In addition, we include only those twin-years for which we have non-missing observations for both twins. Our final sample contains 2,466 identical twins with a total of 17,510 twin-year observations between 1999 and 2007. In Panel B, we report birth weight and sociodemographic characteristics, separately for the lowest- and the highest-birth-weight quartiles, and for the entire sample. For some sociodemographic variables, such as age, birth order, number of siblings, and years of education, there are some clear differences between the lowest and the highest quartiles. It is possible that birth weight affects investor behavior directly as well as indirectly through its effect on such sociodemographic determinants. We address this possibility in our analyses.

The average birth weight of the twins in our sample is 2,414 grams (g), slightly below the commonly used low-birth-weight cutoff of 2,500 g.[9] This average birth weight is below the typical population average, but similar to what other studies have reported for the birth weight of twins (see, e.g., Behrman and Rosenzweig 2004; Black, Devereux, and Salvanes 2007).

Figure 1 shows that the distribution of birth weight for males and females in our sample of identical twins is indeed centered on the left relative to the population distributions. The population distributions are based on all U.S. live births between January and March of 1950 (historical birth-weight data for Sweden are not available before 1973).[10] We address the implications of this difference in distributions for our results in a number of robustness tests.

As we include twin pair fixed effects in our empirical analysis, in the last two columns of Panel B, we report for each variable the mean and standard deviation of the absolute difference between twins in a pair. On average, identical twins in our sample exhibit a difference in birth weight of about 356 g. This within-pair difference is sizeable, and it corresponds, for example, to about 60% of the standard deviation of birth weight across all twins in our data set. Importantly, this difference is unrelated to parental influences or an individual's genetic endowment, which is the same for identical twins.

2.2 Measuring investor behavior

We examine several investor behaviors. At the center of our analysis is the effect of prenatal conditions on financial risk taking later in life. We use several

9 Because birth weight is self reported, measurement error is another source of within-pair differences. We explicitly address the consequences of measurement error in Section V.C.2.

10 The SALT database contains twins born between 1886 and 1958, and the average birth year in our birth-weight sample is 1945. Swedish population birth-weight data are available from 1973. We use U.S. population data for non-African Americans in 1950 as a reasonable proxy. The data are from Table C of the Vital and Health Statistics published by the National Center for Health Statistics (Series 21, Number 3).

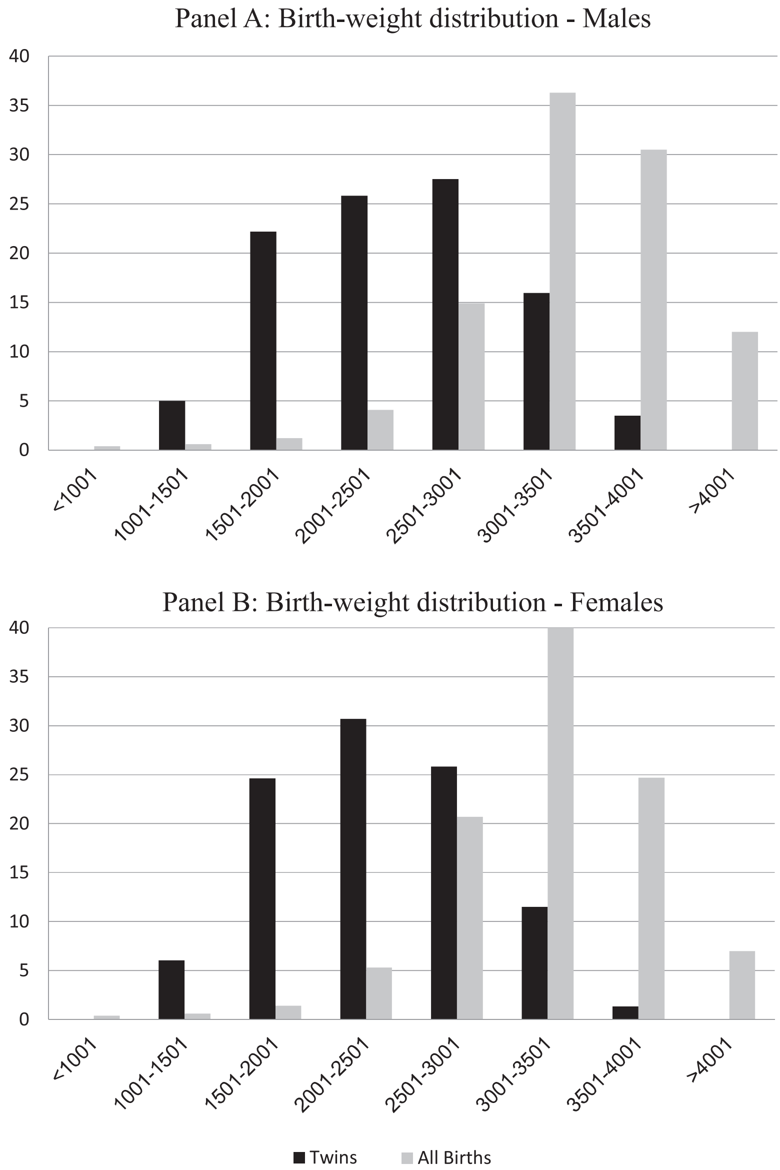

Figure 1
Birth-weight distributions: Twins versus all births
Figure 1 shows the birth weight distribution (by sex) for identical twins in our sample as well as for all non-African American live births in the United States between January and March, 1950. U.S. data are from Table C of the Vital and Health Statistics published by the National Center for Health Statistics (Series 21, Number 3).

standard proxies from the extant literature on financial risk taking. Our first measure is the share of risky (equity) assets (*Risky Share*) out of all financial assets (see, e.g., Merton 1969; Samuelson 1969). Our second measure is the volatility of the portfolio of risky financial assets. Specifically, conditional on stock market participation and using 12 monthly return observations, we calculate the annualized, value-weighted portfolio return volatility (*Portfolio Volatility*) for each twin and each year. We also calculate the fraction of risky assets held directly in stocks, as opposed to mutual funds (*Proportion Stocks*).

We also consider the decision to participate in the stock market (*Participation*) and the share of risky assets conditional on participation (*Risky Share* >0). Although the participation decision could reflect several factors, such as risk preferences, information about the risk-return tradeoff, and stock market entry costs, *Risky Share* >0 should largely be determined by risk aversion. We also construct alternative measures of volatility and the proportion invested in stocks. *Total Portfolio Volatility* is the volatility of the entire financial portfolio, consisting of risk-free and risky investments. *Total Proportion Stocks* measures the proportion of all financial assets invested directly in stocks.

We also investigate additional investor behaviors with a documented gender gap: trading and investments in lottery stocks. We analyze trading behavior (*Turnover*), measuring the number of sales transactions in a given year relative to the number of portfolio positions at the beginning of that year (Barber and Odean 2001).[11] We measure investments in lottery stocks (*Proportion Lottery*) as the end-of-year proportion of risky assets invested in lottery-like assets as defined in Kumar (2009). Last, we study investor's preference for skewness, *Portfolio Skewness*, computed from the value-weighted monthly return of the portfolio of risky assets.

In Table 2, Panel A, we present the summary statistics for financial behaviors in our sample of fraternal twins used in the prenatal testosterone analysis. Across the three main risk-taking proxies, *Risky Share*, *Portfolio Volatility*, and *Proportion Stocks*, men take more risk than women do, and females with male co-twins (F_M) take more risk than females with female co-twins (F_F) do. With the exception of *Risky Share* >0, we find a similar pattern for the additional financial risk measures and for *Turnover*, *Proportion Lottery*, and *Portfolio Skewness*.[12]

In Table 2, Panel B, we report corresponding summary statistics for the sample of identical twins used in the birth-weight analyses. Compared with twins in the lowest birth quartiles, twins in the highest quartile hold more risky assets, but they invest (slightly) less in individual stocks, and experience lower volatility in their overall financial portfolio. In particular, higher-birth-weight twins more often participate in the stock market and, conditional on participation, invest more in risky assets. As a consequence, they also have higher *Total Portfolio Volatility*. On average, higher-birth-weight twins invest a smaller fraction of their financial assets in individual stocks, trade more, invest

11 We do not observe the sales prices of mutual funds and therefore cannot calculate a value-based turnover measure.

12 Note that the number of observations varies across outcome variables because some outcome variables require stock market participation or monthly returns that are missing in a few cases.

Table 2
Summary statistics: Investor behaviors

Panel A: Twin testosterone transfer sample (fraternal twins)

	Female with female co-twin (F_F)			Female with male co-twin (F_M)			Male		
	Mean	Std. dev.	*N*	Mean	Std. dev.	*N*	Mean	Std. dev.	*N*
Risky share	41.555	38.340	61099	42.686	38.537	63042	43.901	38.298	106975
Portfolio volatility	14.251	11.471	26690	14.706	11.911	28203	18.296	14.179	49748
Proportion stocks	21.969	35.598	44658	23.579	36.491	46864	35.784	41.183	83231
Participation	73.104	44.342	61099	74.338	43.677	63042	77.804	41.557	106975
Risky share (> 0)	56.845	33.789	44658	57.422	33.935	46864	56.425	34.330	83231
Total portfolio volatility	7.805	8.816	26690	8.108	9.033	28203	9.952	11.166	49748
Total proportion stocks	11.160	23.286	44658	11.985	23.967	46864	18.783	28.945	83231
Turnover	0.181	0.393	31882	0.187	0.410	33576	0.267	0.551	61456
Proportion lottery	0.040	0.149	41334	0.045	0.156	43706	0.067	0.189	79646
Portfolio skewness	2.289	22.124	29659	2.469	22.145	31162	4.526	22.900	54971

Panel B: Birth weight sample (identical twins)

	Lowest-birth-weight quartile			Highest-birth-weight quartile			Entire sample: Observations by twin			Entire sample: Within-twin-pair differences	
	Mean	Std. dev.	*N*	Mean	Std. dev.	*N*	Mean	Std. dev.	*N*	Mean	Std. dev.
Risky share	43.269	37.478	5140	47.510	38.773	2581	44.959	37.494	17510	28.959	29.043
Portfolio volatility	14.925	12.356	1329	14.703	11.434	763	15.263	12.323	4926	11.605	11.642
Proportion stocks	29.965	39.115	3368	29.331	39.787	1774	28.636	38.408	11744	29.458	37.475
Participation	77.646	41.666	5140	81.945	38.472	2581	79.931	40.052	17510	35.604	47.902
Risky share (> 0)	56.389	33.141	3368	58.560	34.265	1774	57.019	33.115	11744	32.369	27.048
Total portfolio volatility	7.827	8.691	1318	8.177	8.264	758	8.387	9.232	4876	7.572	8.630
Total proportion stocks	14.715	25.739	3368	16.779	28.383	1774	14.983	26.100	11744	13.657	22.805
Turnover	0.228	0.456	2036	0.279	0.531	1065	0.242	0.483	7094	0.436	0.559
Proportion lottery	0.059	0.180	3088	0.054	0.159	1600	0.056	0.168	10736	0.109	0.233
Portfolio skewness	0.030	0.222	1890	0.024	0.224	883	0.029	0.226	6448	0.198	0.181

Table 2, Panel A, reports summary statistics for measures of investor behavior for the fraternal twins used in the Twin Testosterone Transfer analyses, separately for women with a female co-twin (F_F), women with a male co-twin (F_M), and for men. Table 2, Panel B, provides similar measures for the identical twins used in the Birth-weight analyses, separately for the lowest-birth-weight quartile, the highest quartile, and the entire sample. The last two columns of Panel B report summary statistics for within-twin-pair differences. All variables are defined in detail in Table A1. *N* provides the total number of twin-year observations.

less in lottery-type assets, and hold portfolios with lower skewness. The last two columns of Panel B again reveal sizeable differences at the twin-pair level.

3. Effects of Prenatal Testosterone on Financial Risk Taking

3.1 Identification and empirical approach

According to the TTT hypothesis, a female who shares the womb with a male co-twin (F_M) is exposed to a higher level of prenatal testosterone than a female who shares the womb with a female co-twin (F_F) does. This increased testosterone exposure is hypothesized to have a masculinizing effect on the brain of female twins. We, therefore, compare the behaviors of F_M twins (i.e., our treatment group) and F_F twins (i.e., our control group).

Using panel data on female fraternal twins, we estimate the following model:

$$y_{ijt} = \beta_0 + \beta_1 I_j^{F_M} + \beta_2 Age_{jt} + \beta_3 Family_j + \epsilon_{ijt}, \quad (1)$$

where y_{ijt} is a measure of investment behavior of twin i of pair j in year t. I^{F_M} is the treatment effect of interest, which is one for an F_M twin, and zero for an F_F twin. We control for age by indicators for individuals below 35 years, between 35–49, between 50–65, and above 65 years. We also control for family characteristics by including the number of non-twin siblings and the birth order of the twins relative to other siblings.

We want to emphasize several aspects of our empirical approach. First, the sex of fraternal twins is determined exogenously relative to parents' and twins' (genetic) characteristics; however, it is possible that F_M and F_F twins differ in systematic ways. As mentioned above, the ratio of F_M to F_F twins in our data is 0.966, whereas probabilities of male and female births in Sweden would imply a ratio of 0.943. This difference could arise because of nonrandom sampling from the population of female twins or because of the lower life expectancy of F_M twins relative to F_F twins.[13] We address these concerns with a number of robustness checks.

Second, though this study identifies treatment effects for female twins, it provides broader insights into the importance of naturally occurring variation in prenatal testosterone that is endogenously generated by human fetuses *in utero*.[14] By design, we focus entirely on organizational effects of *prenatal* testosterone as opposed to the effects of circulating testosterone later in life.[15]

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[13] We thank an anonymous referee for this observation.

[14] Though there is substantial within-gender variation in testosterone, male fetuses, on average, produce higher levels of testosterone than female fetuses do. In addition to different levels of prenatal testosterone, male and female fetuses also differ with respect to the presence of testosterone receptors.

[15] Men generally have higher levels of circulating testosterone during puberty and in adulthood than women do. Circulating testosterone can be measured in saliva or blood, and exogenously manipulated in experiments. Some studies have examined the effects of circulating testosterone on financial-risk preferences, but the evidence is so far inconclusive. More specifically, higher circulating testosterone has been found to increase risk taking in

Finally, because a female fetus, on average, generates significantly less prenatal testosterone compared with a male fetus (e.g., Kuijper *et al.* 2013), we expect the strongest treatment effect for females who share the womb with a male co-twin. For a male who shared the womb with another male, the expected effect is ambiguous, as both male co-twins generate testosterone. It is unknown if this effect is additive beyond the normal exposure generated by one male fetus.[16]

3.2 Main results

3.2.1 Prenatal testosterone and financial risk taking. In Table 3, Panel A, we present our estimates of the effect of prenatal testosterone on financial risk much later in life. For *Risky Share*, *Portfolio Volatility*, and *Proportion Stocks*, we report the differential effect of having a male co-twin versus a female co-twin.[17]

In all cases, we find that females who shared the womb with a male co-twin (F_M) take significantly more financial risk than females who shared the womb with a female co-twin (F_F) do. Focusing on the specifications with controls (i.e., Columns [2], [4], and [6]), we find that an F_M twin allocates about 1.24 percentage points more of her financial assets to equities compared with an F_F twin. This treatment effect corresponds to an increase of about 3% compared with the mean equity allocation (41.6%) of the control group of F_F twins. Similarly, a treated female's portfolio exhibits a 3% higher volatility and a 14% higher allocation to individual stocks relative to mutual funds in comparison with the control group.[18]

In Panel B, we consider alternative measures of financial risk taking. In Columns (1) and (2), we report estimation results from a linear probability model of *Participation*. Controlling for age and family characteristics reduces the size of the treatment effect, making it statistically insignificant. However, examining the effect on the share of risky assets conditional on participation (*Risky Share* >0) in Columns (3) and (4), we find that the controls for age and family characteristics lead to an increase in the size of the treatment effect,

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investment games in the laboratoty in men (e.g., Apicella *et al.* 2008) or only in women and not in men (e.g., Sapienza, Zingales, and Maestripieri 2009).

16 We also note that we do not expect a feminization of the brain of male twins with female co-twins because "ovarian-estrogen-mediated feminization [largely] takes place after the individual is free from the maternal-hormonal environment of the womb" (e.g., Baron-Cohen, Lutchmaya, and Knickmeyer 2004). Importantly, exposure to testosterone occurs before the female fetal ovaries are functional (in the third trimester) and makes males unresponsive to subsequent exposure to estrogens. In other words, masculinization must *not* have occurred for feminization to occur (e.g., Fitch and Denenberg 1998 and the discussion following the article).

17 Because all measures of financial risk taking have nonnegative values, we employ a standard Tobit model with zero as the lower bound. All standard errors are double clustered by individual and year.

18 *Risky Share* decreases monotonically with age (e.g., Barsky *et al.* 1997), whereas *Proportion Stocks* increases until age 65, possibly reflecting increasing familiarity with individual stocks over the course of the working life. Although *Portfolio Volatility* is lower for those in retirement age, no monotonic association with age exists until age 65.

Table 3
The Effect of having a male co-twin

Panel A: Financial risk taking

	Risky share		Portfolio volatility		Proportion stocks	
	(1)	(2)	(3)	(4)	(5)	(6)
Male co-twin (F_M)	1.591**	1.242**	0.456***	0.386***	3.512***	2.984**
	(0.013)	(0.046)	(0.003)	(0.010)	(0.005)	(0.016)
Age less than 35		21.004***		2.790***		−13.702***
		(0.000)		(0.001)		(0.000)
Age less than 50		16.332***		3.563***		−2.715
		(0.000)		(0.000)		(0.350)
Age less than 66		12.483***		2.284***		3.732*
		(0.000)		(0.000)		(0.087)
Number of siblings		−0.743		0.061		−0.432
		(0.188)		(0.651)		(0.526)
Birth order		0.400		−0.150		−0.740
		(0.330)		(0.156)		(0.294)
Intercept	33.645***	23.761***	14.251***	12.496***	−9.068***	−7.053***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.004)
N	124,141	124,141	54,893	54,893	91,522	91,522
R-squared	0.000	0.002	0.000	0.002	0.000	0.001

Panel B: Alternative measures of financial risk taking

	Participation		Risky share > 0		Total portfolio volatility		Total proportion stocks	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Male co-twin (F_M)	1.233**	0.747	0.578	0.731	0.314**	0.303**	2.037***	1.752**
	(0.025)	(0.176)	(0.223)	(0.108)	(0.011)	(0.012)	(0.010)	(0.024)
Age less than 35		13.000***		11.400***		3.560***		−3.282**
		(0.000)		(0.000)		(0.000)		(0.049)
Age less than 50		10.959***		8.009***		3.398***		2.678*
		(0.000)		(0.000)		(0.000)		(0.088)
Age less than 66		12.082***		1.981**		1.614***		3.787***
		(0.000)		(0.035)		(0.000)		(0.009)
Number of siblings		−1.111***		0.366		0.090		−0.203
		(0.007)		(0.315)		(0.244)		(0.634)
Birth order		0.471		−0.050		−0.084		−0.626
		(0.166)		(0.856)		(0.248)		(0.166)
Intercept	73.104***	65.538***	56.845***	52.866***	7.630***	5.963***	−9.148***	−9.717***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
N	124,141	124,141	91,522	91,522	54,893	54,893	91,522	91,522
R-squared	0.000	0.001	0.000	0.001	0.000	0.003	0.000	0.001

Table 3, Panel A, reports results from regressions of annual measures of financial risk taking of female fraternal twins between 1999 and 2007 onto an indicator variable for women with a male co-twin ("Male co-twin") without and with additional controls. Table 3, Panel B, reports corresponding results for alternative annual measures of risk-taking. We use a Tobit model in all cases except for Columns (1) and (2) of Panel B, where we use a linear probability model. For each model, we report the coefficient estimates, as well as the corresponding *p*-values. *p*-values are based on double-clustered standard errors, robust for correlation across years within same individuals and across individuals within the same year. All variables are defined in detail in Appendix Table A1. *N* provides the number of observations used in each estimation. *R-squared* denotes the *pseudo R-squared*, except for Columns (1) and (2) of Panel B where it denotes the coefficient of determination. Levels of significance are denoted as follows: * if $p < 0.10$; ** if $p < 0.05$; *** if $p < 0.01$.

which, in Column (4), corresponds to a 1.3% increase in *Risky Share* > 0 relative to the control group, with a p-value of 10.7%.

Finally, in Columns (5) through (8), we consider *Total Portfolio Volatility* and *Total Proportion Stocks* as outcomes. The relative size of the treatment effect, which is statistically significant in both cases, is similar to the results in Panel A.

Our evidence is consistent with the TTT hypothesis. A female twin with a male co-twin takes more financial risk, potentially reflecting the partial masculinization of the brain resulting from increased exposure to prenatal testosterone. This result draws attention to the importance of the fetal environment and offers insights into a possible biological perspective on the gender gap in financial risk taking.

3.2.2 The gender gap in financial risk taking. Differential exposure to prenatal testosterone is considered a primary determinant of the development of a male versus female phenotype. Therefore, to compare the economic magnitude of the estimated treatment effect with the overall difference in risk taking between men and women, we add fraternal male twins to our sample and re-estimate Equation (1), including a *Male* indicator variable.

Consistent with previous studies (e.g., Croson and Gneezy 2009; Sundén and Surette 1998), Table 4 reveals a significant gender gap in the three major risk-taking measures. For example, the estimated coefficient on the *Male* indicator is 3.30 percentage points (i.e., men's *Risky Share* is about 8% higher than that of women).

We also report the ratio of the effect of prenatal testosterone to the gender gap. For *Risky Share*, we find that the treatment effect is about 38.6% (=1.273/3.299) of the gender gap. That is, a female who shared the womb with a male, on average, has a 38.6% smaller gender gap compared with a female in the control group. For the other two measures, we find somewhat smaller effects: 10% for *Portfolio Volatility* and 11% for *Proportion Stocks*.

To the best of our knowledge, no human data exist on the magnitude of the increase in prenatal testosterone because of a male co-twin. Nonetheless, animal studies on mice suggest that testosterone transfer from male fetuses increases the blood testosterone levels in female fetuses by about 10% of the difference in testosterone levels between male and female fetuses (e.g., vom Saal and Bronson 1980). Assuming that these studies have some relevance for humans and that the relationship between testosterone levels and risk taking is approximately linear, our estimates of the treatment effect relative to the overall gender gap would appear plausible.[19]

[19] Gender differences in general reflect not only biological, but also social factors. Given the strong emphasis on gender equality in Sweden (e.g., Guiso *et al.* 2008), our data on Swedish twins might be relatively less influenced by gender identity effects.

Table 4
The effect of having a male co-twin and the gender gap

	Risky share (1)	Portfolio volatility (2)	Proportion stocks (3)
Male co-twin (F_M)	1.273**	0.380**	2.931**
	(0.034)	(0.012)	(0.013)
Male	3.299***	3.923***	26.190***
	(0.000)	(0.000)	(0.000)
Age less than 35	19.378***	3.005***	−12.190***
	(0.000)	(0.001)	(0.000)
Age less than 50	15.654***	4.151***	0.336
	(0.000)	(0.000)	(0.885)
Age less than 66	11.477***	2.604***	3.451**
	(0.000)	(0.000)	(0.039)
Number of siblings	−0.775	−0.057	−0.345
	(0.123)	(0.655)	(0.445)
Birth order	0.327	−0.012	−0.443
	(0.330)	(0.832)	(0.332)
Intercept	24.828***	12.139***	−6.574***
	(0.000)	(0.000)	(0.000)
Ratio of F_M to male	0.386**	0.097***	0.112***
	(0.020)	(0.009)	(0.009)
N	231,116	104,641	174,753
R-squared	0.002	0.004	0.005

Table 4 reports results from Tobit regressions of annual measures of financial risk taking of female and male fraternal twins between 1999 and 2007 onto an indicator variable for women with a male co-twin ("Male co-twin"), an indicator variable for men ("Male"), and additional controls. For each model, we report the coefficient estimates and the ratio of the male co-twin effect to the male effect, as well as the corresponding p-values. p-values are based on double-clustered standard errors, robust for correlation across years within same individuals and across individuals within the same year. All variables are defined in detail in Table A1. N provides the number of observations used in each estimation. *R-squared* denotes the *pseudo R-squared*. Levels of significance are denoted as follows: * if $p<0.10$; ** if $p<0.05$; *** if $p<0.01$.

The effect of prenatal testosterone on the brain is of primary interest for understanding the gender gap in financial decisions. Nevertheless, a male co-twin could lead to the masculinization of the female fetus along other dimensions.[20] In untabulated results, we apply our empirical model to a subset of slightly older female twins included in the SALT database for which we have data on birth weight, adult height, and body mass index (*BMI*). Consistent with Glinianaia *et al.* (1998), who document larger birth weight for females with male co-twins, we find that having a male co-twin has significantly positive (at the 10% level) effects on birth weight, adult weight, and *BMI*. The treatment effects for birth weight, adult weight, and *BMI* account for 13%, 2%, and 10% of the respective gender gaps.[21]

Our evidence suggests that differences in prenatal testosterone between men and women could explain a significant proportion of the observed gender gap in

[20] Because the effect of testosterone also depends on the presence of testosterone receptors that can vary across different tissues, this does not have to be the case. Nevertheless, animal studies document that the masculinization that ocurs when a male fetus develops next to a female fetus causes anatomic and physiological consequences in addition to behavioral effects (e.g., vom Saal and Bronson 1980).

[21] For adult height, the treatment effect is positive, but small in magnitude and statistically insignificant.

financial risk taking, complementing social explanations explored by D'Acunto (2014).

3.3 Robustness

Our tests of the TTT hypothesis rely on the assumption that female twins with male co-twins (F_M) differ from female twins with female co-twins (F_F) only in their conditions in the womb. However, male twins could shape their female co-twins' preferences through social interaction from early years to adulthood. Moreover, the gender of the co-twin might not be randomly assigned in our sample, and F_M twins could differ from F_F twins along some relevant parental or family characteristics. We address these concerns in this section.

3.3.1 Social interaction effects. The ideal test to rule out social interactions would be to analyze twins separated since birth. Although a few cases of twins raised separately exist, this sample is too small, and we cannot rule out communication during our sample period. As an alternative, we control for communication, travel distance, and portfolio overlap between the two twins. If contemporaneous social interactions drive our results, the effect of a male co-twin should be stronger among those twins that are more likely to have frequent social interactions.

We proxy for high social interaction in three ways: above median communication and contact frequency, as measured in the Swedish Twin Registry surveys; below median travel time;[22] and more than 50% of the portfolio invested in the same securities. We add to our baseline model in Equation (1) indicators for twins that are more likely to interact during our sample period, as well as interaction terms between these indicators and our treatment indicator, I^{F_M}. If social interactions determine our results, the direct effect of a male co-twin in these specifications should decrease, potentially to zero.

The results in Table 5 reveal that the direct effect of a male co-twin is statistically significant in six out of nine cases, and the point estimates are similar (or slightly larger) in seven out of nine cases, compared with previous estimates. The interaction term is significantly positive only in one of the nine specifications: the treatment effect on the *Proportion Stocks* increases from 2.88 to 10.00 percentage points in the case of higher portfolio overlap.

Social interactions between twins do not easily explain our results. We observe elevated financial risk-taking propensities even among females who are less likely to frequently interact with their male co-twins. We reach a similar conclusion when we perform the same analysis on the alternative risk-taking measures (see Table A2).

[22] We acknowledge that nowadays geographic distance may be an imperfect measure of communication. The results are similar if we use living in different regions or cities to proxy for geographic distance (untabulated).

Table 5
Social interactions

	Risky share			Portfolio volatility			Proportion stocks		
	Contact frequency (1)	Travel distance (2)	Portfolio overlap (3)	Contact frequency (4)	Travel distance (5)	Portfolio overlap (6)	Contact frequency (7)	Travel distance (8)	Portfolio overlap (9)
Male co-twin (F_M)	2.549**	1.585*	1.820***	0.339	0.521***	0.419**	0.797	2.682	2.876**
	(0.016)	(0.061)	(0.003)	(0.234)	(0.007)	(0.050)	(0.710)	(0.105)	(0.021)
More contacts	−0.669			−0.244			−3.599*		
	(0.559)			(0.305)			(0.079)		
More contacts $\times F_M$	−2.921*			−0.035			2.514		
	(0.056)			(0.917)			(0.360)		
Shorter travel distance		−2.421***			−0.322			−3.553**	
		(0.007)			(0.125)			(0.039)	
Shorter travel distance $\times F_M$		−0.852			−0.298			0.450	
		(0.497)			(0.316)			(0.847)	
High portfolio overlap			26.598***			1.469**			18.980***
			(0.000)			(0.016)			(0.000)
High portfolio overlap $\times F_M$			−3.965**			−0.078			7.128*
			(0.010)			(0.868)			(0.075)
Additional controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	124,141	124,141	124,141	54,893	54,893	54,893	91,522	91,522	91,522
R-squared	0.002	0.002	0.004	0.002	0.002	0.002	0.001	0.001	0.002

Table 5 reports results from Tobit regressions of annual measures of financial risk taking of female fraternal twins between 1999 and 2007 onto an indicator variable for women with a male co-twin ("Male co-twin"), proxies for high social interactions, as well as interactions between the indicator variable for women with a male co-twin and proxies for high social interactions. Additional controls are the same control variables used in Table 3. Proxies for high social interactions are: an indicator for twin pairs with above median contact frequency, an indicator for twin pairs with below median travel distance between twins' primary residences, and an indicator for twin pairs with more than 50% portfolio overlap. For each model, we report the coefficient estimates, as well as the corresponding p-values. p-values are based on double-clustered standard errors, robust for correlation across years within same individuals and across individuals within the same year. All variables are defined in detail in Table A1. N provides the number of observations used in each estimation. *R-squared* denotes the *pseudo R-squared*. Levels of significance are denoted as follows: * if $p < 0.10$; ** if $p < 0.05$; *** if $p < 0.01$.

3.3.2 Effects of male siblings. We also investigate if a more general male sibling effect could cause our results. For example, a female with a male co-twin may be exposed to relatively more aggressive or risk-taking male behaviors when growing up. By way of imitation, she could adopt such behaviors and later in life take more financial risk. Differently from an effect of prenatal testosterone, such an effect would not be limited to male co-twins, but should occur with any male sibling.

Accordingly, we analyze if "masculinization effects" in financial risk taking occur for females with male siblings. Ideally, we would draw a random sample of Swedish families and test if females with male siblings close in age exhibit increased risk taking, in the same way that female twins with male co-twins do. In practice, we have access only to information on the family characteristics of twins in our sample. Hence, we analyze the portfolio choices of the female siblings of the twins in our sample. We conduct this analysis in two ways.

First, we look at families with a total of three siblings, including the twin pair. Because it is difficult to account fully for family structure effects, we design a test that is less likely to be affected by endogenous choices in terms of family structure. Specifically, we compare firstborn nontwin females that are followed by either two male fraternal twins or two female fraternal twins. In both cases, parents decided to have additional children after the firstborn daughter. We, therefore, do not expect any potential selection issues between these two types of families. In the former case, the female firstborn is treated by two male siblings; in the latter case, she is treated by two female siblings.

We report the results in Table 6, Panel A. In the case of *Risky Share* in Column (1), having a male sibling (*Male Sibling*) has a very small positive but statistically insignificant effect (0.173 versus 1.242 in Table 3). For *Portfolio Volatility* and *Proportion Stocks*, the point estimates in Columns (3) and (5) are negative but again are statistically insignificant.

We also control for the age gap between the firstborn female and the twin siblings. *Male Sibling Age Gap* is the age difference (in years) between the firstborn female and the younger male twins; it is zero if the twins are female. *Female Sibling Age Gap* is the age difference (in years) between the first born female and the younger male twins; it is zero if the twins are male. The coefficient estimates for *Male Sibling Age Gap* are negative and not statistically significant in all three cases. Similarly, neither *Female Sibling Age Gap* nor *Male Sibling Age Gap* are ever significantly different from zero. Hence, even after controlling for age differences, we do not find that having a male sibling increases financial risk taking.

In Panel B of Table 6, we consider nontwin females as being "treated" by any male sibling, including non-twins, independent of birth order or family size. Not controlling for age differences, we find a positive, but small and statistically insignificant, effect of having a male sibling in Columns (1), (3), and (5). When controlling for the (absolute) age difference between the female sibling and the male sibling closest in age, the "Male Sibling" effect becomes

Table 6
The effect of having male siblings

Panel A: Families of firstborn female singletons and same-sex fraternal twins

	Risky share		Portfolio volatility		Proportion stocks	
	(1)	(2)	(3)	(4)	(5)	(6)
Male sibling	0.173	−2.608	−0.945	−0.534	−8.043	−2.891
	(0.951)	(0.655)	(0.221)	(0.746)	(0.174)	(0.819)
Male sibling age gap		1.085		−0.076		−2.105
		(0.243)		(0.712)		(0.314)
Female sibling age gap		0.426		0.021		−0.888
		(0.597)		(0.925)		(0.603)
Additional controls	Yes	Yes	Yes	Yes	Yes	Yes
N	5,624	5,624	2,610	2,610	4,449	4,449
R-squared	0.001	0.001	0.001	0.001	0.001	0.002

Panel B: All families

	(1)	(2)	(3)	(4)	(5)	(6)
Male sibling	0.785	−0.102	0.076	−0.180	1.020	0.441
	(0.369)	(0.922)	(0.717)	(0.464)	(0.567)	(0.840)
Male sibling age gap		0.183		0.051*		0.095
		(0.180)		(0.079)		(0.713)
Female sibling age gap		−0.074		−0.034		−0.218
		(0.476)		(0.203)		(0.337)
Additional controls	Yes	Yes	Yes	Yes	Yes	Yes
N	133,560	133,560	60,276	60,276	99,477	99,477
R-squared	0.001	0.001	0.001	0.001	0.003	0.003

Table 6, Panel A, reports results from Tobit regressions of annual measures of financial risk taking of a firstborn female singleton between 1999 and 2007 onto an indicator variable for same-sex male twins ("Male sibling"), as well as the age gap separately for same-sex male twins ("Male sibling age gap") and same-sex female twins ("Female sibling age gap"). Additional controls are the same control variables used in Table 3. Table 6, Panel B, reports corresponding results for any female singleton. For each model, we report the coefficient estimates as well as the corresponding p-values. p-values are based on double-clustered standard errors, robust for correlation across years within same individuals and across individuals within the same year. All variables are defined in detail in Table A1. N provides the number of observations used in each estimation. *R-squared* denotes the *pseudo R-squared*. Levels of significance are denoted as follows: * if $p<0.10$; ** if $p<0.05$; *** if $p<0.01$.

negative in two out of the three cases. Only for *Proportion of Stocks* in Column (6) is the effect positive, but it is small in magnitude (0.441 versus 2.984 in Table 3) and statistically insignificant.[23]

We acknowledge that our tests cannot completely rule out that the prenatal T results are possibly confounded by a general male sibling effect. Even if we do not find that having a male sibling has a significant effect on our outcomes, it could still be the case that the relation between twins is different from the relation between non-twin siblings. Nevertheless, taken together the overall evidence in Tables 5 and 6 does not provide strong support for social interactions between twins—either early or late in life—driving our results. Our evidence is also supported by a study that documents no sibling effects on stock market participation (e.g., Li 2014).

23 We again repeat the analysis performed in Table 6 for the alternative risk-taking measures, reaching very similar conclusions. See Table A3 for details.

3.3.3 Sample selection. To investigate potential sample selection, we first test if parental characteristics at the birth of the female twin predict the gender of the co-twin. We regress the treatment indicator I^{F_M}, which is one for F_M twins and zero for F_F twins, on those parental characteristics that are predetermined at birth and not endogenous to the sex of the twins (e.g., parents of two female twins might behave differently from parents of opposite sex twins). Most of our financial variables come from the Tax Registry between 1999–2007 and, hence, are not suitable for this analysis. We use three variables plausibly predetermined at the twin birth: parental age and education, and twins' birthplace.[24]

In Table A4, we document that only the education of the mother appears significant in predicting the gender of the co-twin (Columns 1 to 3). The negative sign of these coefficients would imply that mothers with more years of education are less likely to have opposite-sex twins as compared with two female twins. Given the positive relation between IQ and education and stock market participation and financial risk taking documented in the literature (e.g., Grinblatt, Keloharju, and Linnainmaa 2011) and assuming that parents with higher education influence their children toward more financial risk taking, this sample selection issue—if anything—would bias our result toward not finding an effect of having a male co-twin.

As an additional robustness check, we estimate the effect of a male co-twin for those females that, in our records, appear as not having nontwin siblings. This test will account for any possible effect of family composition and birth order. Untabulated results reveal stronger treatment effects for this subset of female twins.

Finally, we also estimate our treatment effect, including a large set of sociodemographic controls, such as years of education, net worth, disposable income, income volatility, business ownership, marital status, number of children, health status, and birth-location fixed effects.[25] In this specification, we absorb any effect of a male co-twin that operates through these controls, and our treatment indicator I^{F_M} will only reflect the direct effect on financial risk taking. For example, if the effects of maternal education (see Table A4) operate through an increase in education of the twins, this effect would be accounted for in this robustness check.

In Table A5, we report these results for all our measures of financial risk taking. Although the treatment effect decreases and is statistically insignificant for *Risky Share* and *Participation*, our results are largely unchanged for all other risk-taking measures.

[24] We perform this analysis on a subset of female twins with nonmissing parental data. Though parental education is recorded during our sample period, we assume that it is a reasonable proxy for the education level at the twin birth. We include the same controls as in Equation (1).

[25] Given the significant increase in the *R-squared* of the regressions with birth location fixed effects (Table A4, Columns [3], [6] and [8]), we include also these fixed effects in Table A5.

Overall, we conclude that sample selection or sociodemographic characteristics associated with F_F and F_M twins do not drive our results.

4. Effects of Birth Weight on Financial Risk Taking

4.1 Identification and empirical approach

Birth weight is the most widely available and used summary measure of the prenatal environment. In this section, we analyze the effect of birth weight on financial risk taking later in life. Using data on identical twins, we use the following model specification:

$$y_{ijt} = \delta_0 + \delta_1 BW_{ij} + a_j + c_j + \omega_{ijt}, \quad (2)$$

where y_{ijt} is a measure of financial risk taking of twin i of pair j in year t. BW_{ij} is a twin's birth weight. a_j and c_j are, respectively, unobservable genetic endowments and environmental effects common to a twin pair (e.g., the mother's health during the pregnancy or the parents' socioeconomic status).

Birth weight may be correlated with these genetic endowments and common environmental effects. Therefore, we include twin-pair fixed effects to isolate the individual-specific effects of the prenatal environment, such as better or worse nutritional intake of one twin relative to the other twin. Specifically, by simultaneously accounting for a_j and c_j, twin-pair fixed effects result in an unbiased estimate of δ_1 (e.g., Behrman and Rosenzweig 2004; Black, Devereux, and Salvanes 2007).

We estimate Equation (2) using ordinary least squares. All reported standard errors are double clustered by individual and year.

4.2 Main results

The effect of birth weight on risk taking is unclear *ex ante*. On the contrary, those with higher birth weight might be better off and therefore able to take more risk in financial markets (e.g., Behrman and Rosenzweig 2004; Black, Devereux, and Salvanes 2007). Those with lower birth weight might take more risk later in life to mitigate the effects of a poor start (e.g., Metcalfe and Monaghan 2001; Hack *et al.* 2002).

Table 7, Panel A, reports the effect of birth weight, measured using the natural logarithm (*Birth Weight (ln)*), on financial risk taking. In Columns (1), (3), and (5), we report results without twin-pair fixed effect; in Columns (2), (4), and (6), we include twin-pair fixed effects.[26] The inclusion of twin pair fixed effects significantly increases the *R-squared*. This result is not surprising, and it reflects the significant commonality between identical twins. The importance of genetic and common environmental effects for risk taking is consistent with studies (e.g., Barnea, Cronqvist, and Siegel 2010; Cesarini *et al.* 2010).

[26] In the specification without twin-pair fixed effects, we also control for gender, as we use both male and female identical twins.

Table 7
The effect of birth weight

Panel A: Financial risk taking

	Risky share		Portfolio volatility		Proportion stocks	
	(1)	(2)	(3)	(4)	(5)	(6)
Birth weight (ln)	4.950**	5.958*	−0.224	−2.703***	−5.752*	−12.061**
	(0.042)	(0.095)	(0.798)	(0.001)	(0.098)	(0.011)
Female	1.875		−4.413***		−15.782***	
	(0.207)		(0.000)		(0.000)	
Twin-pair fixed effects	No	Yes	No	Yes	No	Yes
N	17,510	17,510	4,876	4,876	11,744	11,744
R-squared	0.001	0.417	0.025	0.460	0.033	0.581

Panel B: Alternative measures of financial risk taking

	Participation		Risky share > 0		Total portfolio volatility		Total proportion stocks	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Birth weight (ln)	6.260**	10.800***	1.489	2.603	0.828	−1.361	−0.314	−5.318*
	(0.023)	(0.006)	(0.558)	(0.451)	(0.330)	(0.325)	(0.891)	(0.077)
Female	0.200		1.763		−2.594***		−9.259***	
	(0.889)		(0.277)		(0.000)		(0.000)	
Twin-pair fixed effects	No	Yes	No	Yes	No	Yes	No	Yes
N	17,510	17,510	11,744	11,744	4,876	4,876	11,744	11,744
R-squared	0.001	0.459	0.001	0.398	0.015	0.457	0.030	0.441

Table 7, Panel A, reports results from linear regressions of annual measures of financial risk taking of identical twins between 1999 and 2007 onto birth weight ("Birth weight (ln)") without and with twin-pair fixed effects. In the models without twin fixed effects, we add an indicator variable for women ("Female"). Table 7, Panel B, reports corresponding results for alternative measures of financial risk taking. For each model, we report the coefficient estimates, as well as the corresponding p-values. p-values are based on double-clustered standard errors, robust for correlation across years within same individuals and across individuals within the same year. All variables are defined in detail in Table A1. N provides the number of observations used in each estimation. *R-squared* denotes the coefficient of determination. Levels of significance are denoted as follows: * if $p<0.10$; ** if $p<0.05$; *** if $p<0.01$.

We find that birth weight has a positive effect on *Risky Share*. The estimated effect is larger, but the statistical significance is somewhat weaker, in the second column where we also include twin-pair fixed effects. In the fixed-effects model, a one-standard-deviation increase in *Birth Weight (ln)* increases the *Risky Share* by about 1.46 percentage points, or about 3.3% of the mean allocation in the entire sample (45.0%).

We also find that birth weight has a negative effect on *Portfolio Volatility* and *Proportion Stocks*. Both effects are highly statistically significant after accounting for twin-pair fixed effects. The estimates in Column (4) imply that a one-standard-deviation increase in *Birth Weight (ln)* decreases the *Portfolio Volatility* by about 4.6% relative to the sample mean of 15.3%. Estimates in Column (6) imply that an analogous change in birth weight generates an even larger effect and reduces the *Proportion Stocks* by about 10.4% of the sample mean (28.6%).

In Panel B of Table 7, we report results for alternative measures of financial risk taking. As in Panel A, controlling for unobserved, time-invariant twin-pair heterogeneity is important. Based on Columns (2) and (4), we find a statistically significant and positive effect of birth weight on stock market participation. We do not find a significant effect on risky assets, conditional on participation.

Based on the results in Panel A, higher-birth-weight individuals are more likely to hold risky assets, but conditional on holding risky assets, they choose less volatile portfolios with a smaller fraction of individual stocks to mutual funds. The *net* effect of birth weight on *Total Portfolio Volatility* is negative but not statistically significant (Column [6]). For *Total Proportion Stocks*, the net effect is negative and statistically significant at the 10% level in the relevant fixed-effect specification of Column (8).

The finding that lower-birth-weight individuals are less likely to invest in risky assets is consistent with adverse prenatal conditions, experienced in the womb, increasing stock market participation costs. Conditional on holding any risky asset, however, lower-birth-weight twins hold more volatile portfolios with a higher fraction of individual stocks, consistent with compensatory behavior in response to unfavorable starting conditions.

Biologists have pointed out that selection will favor compensatory strategies if they increase the chances of reproductive success, even if they have some negative aspects, such as shortening life (Metcalfe and Monaghan 2001). In the financial domain, Robson (1992) and Roussanov (2010) have examined the implications of status concerns and the desire to get ahead of others. Consistent with our findings that low-birth-weight investors take more risk and prefer individual stocks over well-diversified mutual funds, Roussanov (2010) finds that status-concerned investors prefer idiosyncratic risk over aggregate risk. Even though this compensatory behavior has not been documented before in the economic literature, it is worth clarifying that existing studies have largely focused on levels, for example, of income, but not on variability/volatility or, more broadly, risk taking.

Finally, this evidence questions if the previous prenatal testosterone results are explained by differences in birth weight. We have reestimated Equation (1), adding *Birth Weight (ln)* to the model. In untabulated results, we find that our estimates of the effect of a *Male Co-Twin* do not change after we control for birth weight. In other words, the effect of prenatal testosterone is orthogonal to general prenatal conditions as captured by birth weight.

4.3 Robustness

4.3.1 External validity. The fact that twins on average have lower birth weight than singletons do is explained entirely by twinning rather than the parental characteristics of the twin parents (Behrman and Rosenzweig 2004). Given the lower-birth-weight of twins, we examine the external validity of our results. If the effect of birth weight on risk taking varies as a function of the level of birth weight, our results would be different if estimated on a random sample of the population with a higher average birth weight.

We address this concern in two ways. First, we perform a weighted regression, using weights such that we replicate the birth weight distributions

Table 8
The effect of birth weight: Twins versus the population

Panel A: Weighted regression results

	Risky share (1)	Portfolio volatility (2)	Proportion stocks (3)
Birth weight (ln)	1.787	−7.173**	−27.430**
	(0.860)	(0.045)	(0.049)
Twin-pair fixed effects	Yes	Yes	Yes
N	17,510	4,876	11,744
R-squared	0.503	0.491	0.653

Panel B: Subsample regressions

	Risky share (1)	Portfolio volatility (2)	Proportion stocks (3)
Birth weight $<2,500$g			
Birth weight (ln)	8.862	1.659	−14.006
	(0.147)	(0.405)	(0.113)
Twin-pair fixed effects	Yes	Yes	Yes
N	9,320	2,576	6,275
R-squared	0.486	0.510	0.674
Birth weight $\geq 2,500$g			
Birth weight (ln)	5.669	−8.200**	−39.504***
	(0.554)	(0.015)	(0.006)
Twin-pair fixed effects	Yes	Yes	Yes
N	8,190	2,300	5,469
R-squared	0.465	0.506	0.628

Table 8, Panel A, reports results from linear regressions of annual measures of financial risk taking of identical twins between 1999 and 2007 onto birth weight ("Birth weight (ln)") and twin-pair fixed effects. Each observation is weighted depending such that the distributing of the weighted birth weight represents the population distribution of birth weight as shown in Fig. 1. Table 8, Panel B, reports results for unweighted linear regressions perfomed separately for twins with birth weight below 2,500 g and twins with birth weight above 2,500 g. All regressions include twin-pair fixed effects. For all models, we report the coefficient estimates, as well as the corresponding p-values. p-values are based on double-clustered standard errors, robust for correlation across years within same individuals and across individuals within the same year. All variables are defined in detail in Table A1. N provides the number of observations used in each estimation. *R-squared* denotes the coefficient of determination. Levels of significance are denoted as follows: * if $p<0.10$; ** if $p<0.05$; *** if $p<0.01$.

for the U.S. population (as shown in Figure 1). Second, we split our sample into two groups, using the low-birth-weights cutoff of 2,500 g. We analyze our three measures of financial risk taking, including twin-pair fixed effects in all cases.

Table 8 Panel A reports the weighted regression results. The effect of birth weight on *Risky Share* is substantially smaller and no longer statistically significant when estimated with appropriate population weights. At the same time, the effects for *Portfolio Volatility* and *Proportion Stocks* are statistically significant and at least twice as large (in absolute size) as our previous estimates.

In Panel B of Table 8, we report separate results from unweighted regressions for twins with birth weights below and above 2,500 g. For *Risky Share*, we find relatively large positive, but statistically insignificant, point estimates for both subsamples. Interestingly, for *Portfolio Volatility*, the negative effect of birth weight is only present in the subsample of twins with higher birth weight. For *Proportion Stocks*, birth weight has a negative effect in both subsamples, but the effect is larger and statistically significant in the subsample with higher birth weight.

Taken together, the results in Table 8 suggest the effect of birth weight on *Risky Share* might be limited to samples that include a large number of low-birth-weight individuals, whereas the effects on *Portfolio Volatility* and *Proportion Stocks* seem to be present and possibly stronger in the general population.

Finally, we investigate if the effect of birth weight has changed over time, for example, because of medical advances or higher resources devoted to those with a less favourable prenatal environment. We are limited in our ability to address this question because we only have birth-weight data for twins born before 1958, and we observe their financial decisions only for a few years, such that we cannot distinguish between life cycle and cohort effects. Nevertheless, in Figure 2, we document that the within-pair differences in twin birth weight and our three risk-taking measures are substantially constant across different cohorts (i.e., for those born in the 1920s, 1930s, 1940s, and 1950s). In untabulated analyses, we have also included an interaction term between birth weight and birth year in our baseline specifications. For *Risky Share* and *Proportion Stocks*, this interaction term is insignificant; for *Portfolio Volatility*, it is significant and negative, suggesting a stronger effect for more recent birth years. With the caveat that we cannot fully distinguish between life cycle and cohort effects, our results suggest that the effect of birth weight does not appear to decline over time.

4.3.2 Measurement error. Our measure of birth weight likely suffers from measurement error, as it is self-reported and not from archival data. As pointed out in Taubman (1976), estimation with twin-pair fixed effects can lead to an increased attenuation bias relative to OLS estimation if the correlation between the true birth weight of both twins is larger than the correlation of the measurement errors. Because we do not have access to archival birth weight data, we cannot directly test for the effect of measurement error. Instead, we have explored an instrumental variable (IV) approach. We instrument $BirthWeight(ln)$ with an indicator variable that for a given twin pair is one for the twin with the higher birth weight and zero for the other twin (Black, Devereux, and Salvanes 2007). This IV estimation depends on the assumptions that although twins might not recall their exact birth weight, they still remember which of the two twins had the higher birth weight, and that these recollections are not affected by outcomes later in life.

For *Risky Share*, *Portfolio Volatility*, and *Proportion Stocks*, the IV regressions (untabulated) yield point estimates that are, on average, about 66% larger than the fixed effect estimates in Table 7, Panel A. At the same time, the standard errors of the IV estimates are larger, as well, such that in all cases, the 95% confidence interval around the IV point estimate includes the point estimates from the fixed-effect estimation. We therefore conclude that our fixed-effect estimates offer a lower bound of the true effect of $BirthWeight(ln)$ on our key outcomes.

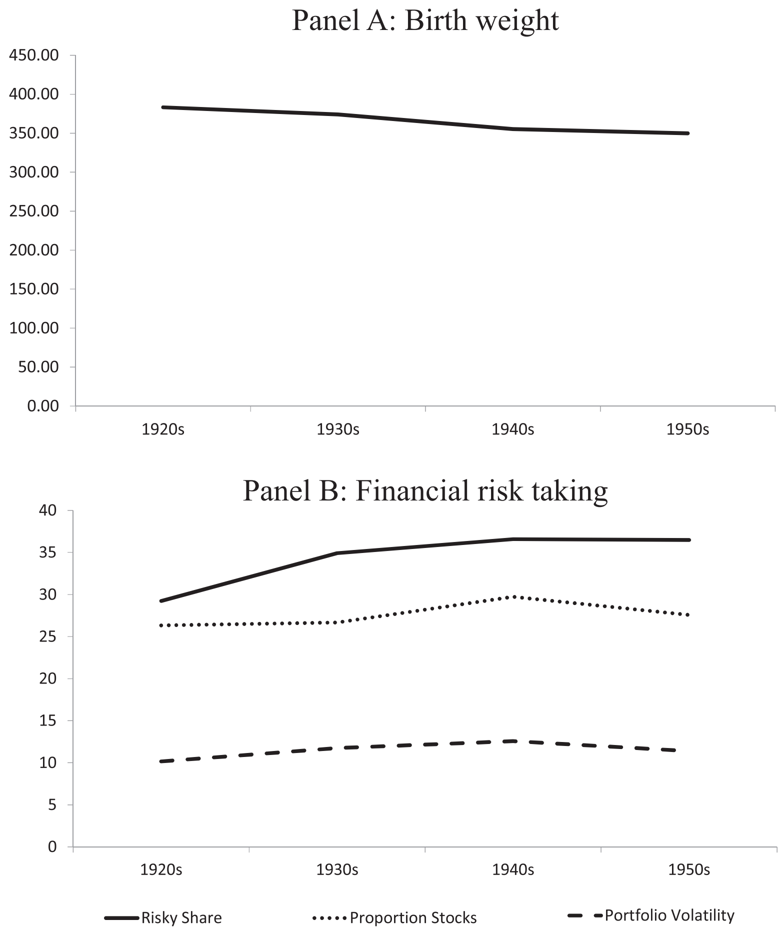

Figure 2
Birth-weight distributions: Twins versus all births
Figure 2 shows the average within-twin-pair difference for *Birth weight* (Panel A) and for *Risky Share*, *Portfolio Volatility*, and *Proportion Stocks* (Panel B) by decade of birth year birth.

4.3.3 Is there a direct effect of birth weight? Birth weight can directly influence financial risk taking, because fetal programming may affect preferences. In addition, birth weight might affect other economic outcomes, such as education, income, or health, that can in turn influence investment decisions (e.g., Behrman and Rosenzweig 2004; Grjibovski, Harris, and Magnus 2005; Black, Devereux, and Salvanes 2007).

To test if birth weight has a direct effect above and beyond known channels, we estimate our baseline model including a large set of control variables suggested by the existing portfolio choice literature: *Net Worth* (e.g., Brunnermeier and Nagel 2008), *Labor Income Volatility* and *Business Owner* (e.g. Heaton and Lucas 2000), cognitive abilities proxied by *Years of Education* (e.g., Grinblatt, Keloharju, and Linnainmaa 2011), and *Poor Health* (e.g., Rosen and Wu 2004), *Single*, *Divorced*, *Number of Children*, *Retired*, and *Disposable Income (ln)*.

In Table A6, we document that the effects of birth weight on our measures of financial risk taking remain largely unchanged, even after controlling for all of the above variables and twin fixed effects. In some cases, the absolute size of the birth weight effect increases.

This evidence suggests the effects of birth weight on financial risk taking are not easily explained by known factors that affect financial risk taking. The prenatal environment, as "summarized" by birth weight, seems to have persistent and direct effects on financial decisions much later in life.

5. Interpretation of Results

Our results so far suggest that prenatal conditions significantly affect financial risk taking later in life. In this section, we analyze additional investor behaviors that could be affected by variation in prenatal testosterone or birth weight. We also discuss the interpretation and implications of our findings by examining whether prenatal conditions affect financial decisions through cognitive abilities or preferences.

5.1 Prenatal conditions and additional investor behaviors

In addition to a gender gap in risk-taking, research in finance has documented gender differences in trading (Barber and Odean 2001) and lottery-type investments (Kumar 2009).[27] We therefore examine if female twins with a male co-twin (F_M) are more likely to trade and hold more lottery-type investments than female twins with a female co-twin (F_F) do.

In Table 9, Panel A, we find evidence that supports these predictions. Female twins with a male co-twin (F_M) have a higher turnover (*Turnover*) by 1.99 percentage points (statistically significant at the 10% level). This corresponds to an increase of about 11% compared to the mean turnover (18.1%) of the control group of F_F twins. The effect on *Proportion Lottery* is even more sizable and statistically significant at the 1% level. F_M twins hold 2.93 percentage points more of lottery-type investments or about 72.5% more compared with the average allocation (4.04%) of the control group of F_F twins. Finally, for *Portfolio Skewness* the estimated treatment effect is also positive, but it is relatively smaller in magnitude and not statistically significant at conventional levels.

27 Using data from a large discount brokerage firm, Barber and Odean (2001) document that men trade 45% more than women. Kumar (2009) finds that men are more likely than women are to invest in lottery-type stocks (i.e., stocks with low price and high idiosyncratic skewness and volatility) consistent with evidence outside of the financial domain that men exhibit higher rates of pathological gambling than women (e.g., Slutske, Jackson, and Sher 2003; Stoletenberg, Batien, and Birgenheir 2007).

Table 9
Additional investor behaviors

Panel A: The effect of having a male co-twin

	Turnover (1)	Proportion lottery (2)	Portfolio skewness (3)
Male co-twin (F_M)	1.987*	2.933***	0.163
	(0.085)	(0.001)	(0.131)
Additional controls	Yes	Yes	Yes
N	65,458	85,040	60,821
R-squared	0.000	0.003	0.000
Panel B: The effect of birth weight			
Birth weight (ln)	−2.484	−2.960*	−5.635***
	(0.565)	(0.086)	(0.001)
Twin-pair fixed effects	Yes	Yes	Yes
N	7,094	10,736	6,448
R-squared	0.294	0.193	0.138

Table 9, Panel A, reports results from Tobit regressions of annual measures of investor behavior of female fraternal twins between 1999 and 2007 onto an indicator variable for women with a male co-twin ("Male co-twin") and additional controls. Table 9, Panel B, reports results from linear regressions of annual measures of investor behavior of identical twins between 1999 and 2007 onto birth weight ("Birth weight (ln)") and twin-pair fixed effects. For each model, we report the coefficient estimates, as well as the corresponding p-values. p-values are based on double-clustered standard errors, robust for correlation across years within same individuals and across individuals within the same year. All variables are defined in detail in Table A1. N provides the number of observations used in each estimation. *R-squared* denotes the *pseudo R-squared* (Panel A) or the coefficient of determination (Panel B). Levels of significance are denoted as follows: * if $p < 0.10$; ** if $p < 0.05$; *** if $p < 0.01$.

In untabulated results, we compare the treatment effect of having a male co-twin with the gender gap for trading and lottery-type investments in our data set. The ratio of the treatment effect and the gender gap is equal to 9.3% for *Turnover* and 19.3% for *Proportion Lottery* (statistically significant at the 10% and 1% level). The magnitude of these ratios is consistent with the evidence presented in Table 4 about financial risk taking.[28]

We also investigate the relation between birth weight and these additional outcome variables. If lower-birth-weight twins engage in compensatory risk-taking behaviors, then we expect their portfolios to exhibit higher skewness and, possibly, a larger fraction of lottery-type assets, as these investments have higher idiosyncratic volatility and skewness. However, there is no clear prediction in terms of birth weight affecting trading activity.

In Table 9, Panel B, we report the corresponding results for the twin-pair fixed effect specification of Equation (2). Consistent with an unclear prediction, we find a negative, but statistically insignificant, effect of birth weight on trading activity. Birth weight has instead a statistically significant (at the 10% level) negative effect on the share of lottery-type stocks. Our estimates imply that a one-standard-deviation decrease in *Birth Weight (ln)* increases the *Proportion Lottery* by about 13% relative to the sample mean (5.6%). The effect of birth weight on skewness is statistically significant at the 1% level and also

28 We do not find a statistically significant gender gap in *Portfolio Skewness*.

economically meaningful. A one-standard-deviation decrease in *Birth Weight (ln)* increases the *Portfolio Skewness* by about 47.8% of the average portfolio skewness in the entire sample (2.9%).

The evidence in Table 9 dovetails nicely with our previous results. First, we find that having a male co-twin increases trading and investments in lottery-type stocks. These results offer further support for masculinization of female financial behaviors because of prenatal testosterone.

Second, we find that lower birth weight considerably increases portfolio skewness and, to a lesser extent, holdings of lottery-type investments. This result is consistent with lower-birth-weight individuals engaging in compensatory behaviors.

5.2 Preferences versus cognitive abilities and biases

The additional results in Table 9 raise the question if prenatal conditions affect investor behavior through cognitive abilities and ultimately investment mistakes or if they directly influence investors' preferences. Frequent trading, more lottery-type investments, and poor diversification (i.e., more individual stocks) are directly related to behavioral biases (Cronqvist and Siegel 2014) and low financial sophistication (Calvet, Campbell, and Sodini 2009). On the contrary, the share of risky assets, portfolio volatility, and portfolio skewness could reflect underlying preferences.

We use mediation analysis to account systematically for the possibility that prenatal conditions can have a direct effect on portfolio choice and also an indirect effect, through cognitive abilities.[29] We control for cognitive skills by using education, income, and net worth as proxies (Grinblatt, Keloharju, and Linnainmaa 2011).[30] We also employ the bias index of Cronqvist and Siegel (2014) as a proxy of financial sophistication. This index reflects the extent to which investors commit a number of investment mistakes.[31]

We conduct the mediation analysis for the three outcome variables most likely to reflect investors' preferences: share of risky assets (conditional on participation), portfolio volatility, and portfolio skewness. For computational ease, we use pure cross-sectional data, by converting time-varying variables into time-series averages. We employ the seemingly unrelated regression model

[29] Our analysis is similar in spirit to Brañas-Garza and Rustichini (2012), who investigate the effect of prenatal testosterone exposure — as measured by the 2D:4D ratio — on risk aversion, with reasoning ability as the mediating factor. The possibility of an indirect effect of prenatal conditions on investor behaviors is suggested by the existing literature. For example, higher birth weight is associated with higher IQ (e.g., Black, Devereux, and Salvanes 2007), and IQ positively influences investment decisions (Grinblatt, Keloharju, and Linnainmaa 2011).

[30] Grinblatt, Keloharju, and Linnainmaa (2011) document that roughly two thirds of the effect of IQ on stock market participation is indeed explained (or mediated) by education, income, and wealth.

[31] We compute the bias index for each individual and for each year in our sample. The index takes the value between zero (high financial sophistication) and ten (low sophistication), aggregating in a linear way the tendency to engage in five different behavioral biases: i) under-diversification; ii) home bias; iii) trend-chasing; iv) trading; and v) holding lottery stocks. For more details on the construction of this index, see Table A1.

by Zellner (1962, 1963) and estimate the following set of equations separately for the three outcomes (y_{ij}) and the two prenatal treatments:

$$y_{ij} = \eta_1 + \lambda_1 PrenatalTreatment_{ij} + \alpha Education_{ij} + \beta Income_{ij} + \gamma NetWorth_{ij} + \delta BiasIndex_{ij} + \Omega_1 BaselineControls_{ij} + \epsilon_{1ij} \quad (3)$$

$$Education_{ij} = \eta_2 + \lambda_2 PrenatalTreatment_{ij} + \Omega_2 BaselineControls_{ij} + \epsilon_{2ij} \quad (4)$$

$$Income_{ij} = \eta_3 + \lambda_3 PrenatalTreatment_{ij} + \Omega_3 BaselineControls_{ij} + \epsilon_{3ij} \quad (5)$$

$$NetWorth_{ij} = \eta_4 + \lambda_4 PrenatalTreatment_{ij} + \Omega_4 BaselineControls_{ij} + \epsilon_{4ij} \quad (6)$$

$$BiasIndex_{ij} = \eta_5 + \lambda_5 PrenatalTreatment_{ij} + \Omega_5 BaselineControls_{ij} + \epsilon_{5ij} \quad (7)$$

As previously, we include age and family structure controls for the prenatal testosterone analyses and twin fixed effects in all the birth weight analyses as *Baseline Controls*.

The coefficient of the direct effect, λ_1, is estimated in Equation (3). The indirect effects are estimated by multiplying the coefficients of each of the mediating factors in Equation (3) with the estimates of the *Prenatal Treatment* effects on each of these factors in the following Equations (4–7). For example, in the case of education as a mediator, the indirect effect of our prenatal treatment is given by the product $\lambda_2\alpha$. Therefore, the combined indirect effect is given by: $\lambda_2\alpha + \lambda_3\beta + \lambda_4\gamma + \lambda_5\delta$.

If the direct effect, λ_1, is significant and dominates the combined indirect effect, we would interpret this result as prenatal conditions affecting a given outcome by shaping preferences. If instead the indirect effect prevails, we would conclude that prenatal testosterone and birth weight influence our outcomes largely through the cognition channel.

In Table 10, Panel A, we present the results relative to prenatal testosterone. For each variable, we first report the coefficient estimates and then the size of the effect relative to the total (direct plus indirect) effect. For ease of comparison, we also report the combined indirect effect. We assess the statistical significance of the direct and indirect effects using bootstrapping methods (Preacher and Hayes 2004; Zhao, Lynch, and Chen 2010).[32]

Having a *Male Co-Twin* has a positive direct effect on *Risky Share* >0, which is statistically significant at the 10% level. This effect is even larger than

[32] We perform 10,000 repetitions with case resampling. Following the convention in this methodology, we account for the fact that the indirect effects are generally non-normally distributed (i.e., usually positively skewed and kurtotic) by estimating asymmetric confidence intervals for the indirect effects.

Table 10
Mediation analysis

Panel A: The effect of having a male co-twin

	Risky share > 0		Portfolio volatility		Portfolio skewness	
	Coeff. (1)	% of total (2)	Coeff. (3)	% of total (4)	Coeff. (5)	% of total (6)
Direct effect:						
Male co-twin (F_M)	0.899*	115.7	0.189	46.4	0.066	33.3
Indirect effect:						
Years of education	0.038**	4.9	0.013***	3.2	−0.002	−1.0
Disposable income (ln)	−0.055**	−7.1	−0.005	−1.2	−0.002	−1.0
Net worth (ln)	−0.054	−6.9	0.000	0.0	0.000	0.0
Bias index	−0.051**	−6.6	0.210**	51.6	0.136**	68.7
Combined indirect effect	−0.122	−15.7	0.218**	53.6	0.132**	66.7
Total (direct + indirect)	0.777		0.407		0.198	
N	11,950		10,415		10,377	

Panel B: The effect of birth weight

	Coeff. (1)	% of total (2)	Coeff. (3)	% of total (4)	Coeff. (5)	% of total (6)
Direct effect:						
Male co-twin (F_M)	2.295	89.4	−0.205	15.7	−4.273***	91.0
Indirect effect:						
Years of education	0.358**	13.9	0.056	−4.3	0.049	−1.0
Disposable oncome (ln)	−0.250	−9.7	−0.061	4.7	−0.084	1.8
Net worth (ln)	−0.334	−13.0	0.082	−6.3	0.087	−1.9
Bias index	0.498**	19.4	−1.175**	90.2	−0.474*	10.1
Combined indirect effect	0.272	10.6	−1.098*	84.3	−0.422	9.0
Total (direct + indirect)	2.567		−1.303		−4.695	
N	2,833		2,570		2,604	

Table 10, Panel A, reports results from a mediation analysis of the direct and indirect effects of having a male co-twin ("Male co-twin") on financial decisions. Table 10, Panel B, reports corresponding results for the direct and indirect effects of birth weight in the presence of twin fixed effects. Mediating variables are education, income, net worth, and a proxy for financial sophistication. Where appropriate, variables represent time-series averages. Statistical significance is established by bootstrapping with 10,000 repetitions. All variables are defined in detail in Table A1. *N* provides the number of observations used in each estimation. Levels of significance are denoted as follows: * if $p < 0.10$; ** if $p < 0.05$; *** if $p < 0.01$.

the *Total Effect* by 15.7%, implying a negative combined indirect effect. While education, income, and the bias index all have statistically significant effects (at the 5% level), they have competing effects (i.e., of opposite signs). As a result, the *Combined Indirect Effect* is indeed negative and not statistically significant at conventional levels. Taken together, this evidence favors an interpretation of the effect of prenatal testosterone on the share of risky assets as largely because of preferences, rather than cognitive abilities.

For both *Portfolio Volatility* and *Portfolio Skewness*, the combined indirect effect is statistically significant at the 5% level. The direct effect is not only smaller in magnitude, but also statistically insignificant. The *Bias Index* largely contributes to this result. Females with a male co-twin choose equity investments with higher volatility and skewness, but this is largely explained by their propensity to make more investment mistakes in general.[33] In other words,

33 The bias index also includes the fraction of lottery stocks, investments that have by definition higher skewness. We are not worried that this index is mechanically related to our outcome variable, *Portfolio Skewness*. In Table 10, Panel B, we indeed present evidence that in the case of birth weight, the bias index does not explain the portfolio skewness.

prenatal testosterone increases the likelihood of making investment mistakes, and this tendency largely explains the higher portfolio volatility and skewness.

In Table 10, Panel B, we report the results of the mediation analysis for birth weight.[34] In the case of *Risky Share* >0, neither the direct nor the combined indirect effect is statistically significant. The lack of a significant direct effect is consistent with the evidence in Table 7, Panel B, documenting how birth weight influences the share of risky assets largely through participation in the stock market.

For *Portfolio Volatility*, the direct effect is insignificant, while the combined indirect effect is statistically significant at the 10% level and represents 84.3% of the *Total Effect* of birth weight. This indirect effect is largely driven by the *Bias Index* and suggests that birth weight decreases the likelihood of investment biases and this effect largely accounts for the lower portfolio volatility.

In the case of *Portfolio Skewness*, we find a statistically significant direct effect that represents 91.0% of the *Total Effect*. We also find evidence of a significant (at the 10% level) indirect effect that accounts for only 10.1% of the total effect. These results lend support to a direct effect of birth weight on preferences for skewness.

Overall, our mediation analysis results in Table 10 highlight that prenatal conditions have the potential to shape cognitive abilities and investment biases, as well as lifetime investment preferences.

6. Conclusion

A large and growing body of literature in economics has documented the importance of the prenatal (i.e., prebirth) environment for economic outcomes much later in life (e.g., Almond and Currie 2011b; Currie 2011). These academic studies have even made their way into mainstream media, for example Paul's (2011) book "Origins: How the Nine Months Before Birth Shape the Rest of Our Lives" and an article in Time magazine summarizing the evidence: The "quality of nutrition [we] received in the womb; the pollutants, drugs and infections [we] were exposed to during gestation [...] shape our susceptibility to disease, our appetite and metabolism, our intelligence and temperament." In this study, we have asked whether the prenatal environment also affects outcomes in the domain of financial decisions.

We find that differences in an individual's prenatal environment explain heterogeneity in investor behavior, in particular with respect to financial risk taking, much later in life. An exogenous increase in exposure to prenatal testosterone "masculinizes" financial decisions and leads to elevated risk taking, more trading, and larger investments in lottery-type assets. We also

[34] We account for twin fixed effects in all cases. Hence, we identify the indirect effect of birth weight controlling for the fact that the channels, such as biases, might have strong genetic determinants (e.g., Cesarini *et al.* 2012; Cronqvist and Siegel 2014).

examine birth weight, the most widely used summary measure of the prenatal environment. Controlling for identical-twin-pair fixed effects, we find those individuals with lower birth weight (i.e., those that experience more adverse prenatal conditions in a general sense) make worse financial decisions, by, for example, not investing in the stock market. At the same time, low-birth-weight investors hold portfolios with higher volatility and skewness, consistent with compensatory behavior. The prenatal environment affects financial decisions directly by shaping investors' preferences. For example, prenatal testosterone has a direct effect on risk preferences, whereas birth weight directly affects skewness-related preferences. However, prenatal testosterone, as well as birth weight, seem to affect the chosen level of portfolio volatility indirectly through their general effect on decision making.

Our results contributes to the understanding of how (prenatal) environmental conditions can shape individuals' behavior in financial markets. Further, our evidence with respect to prenatal testosterone exposure also suggests that biological factors could explain a sizeable proportion of the gender gap in financial decisions, whereas our birth weight results provide novel evidence of the compensatory behavior by those with low birth weight.

Future research may focus on how different prenatal environmental factors, other than testosterone exposure or birth weight, affect financial decisions. Several economists have also emphasized the importance of the *postnatal* early life environment for outcomes much later in life (e.g., Garces, Thomas, and Currie 2002; Cunha and Heckman 2009), which provides another direction for future research.

Table A1
Appendix
Definition of all variables

Variable	Definition
Types of twins	
Fraternal twins	Twins that, on average, have a genetic correlation of 50%, also called dizygotic or non-identical 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.
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.
Measures of investor behavior	
Risky share	The fraction of financial assets invested in equity either directly (individual stocks) or indirectly (equity mutual funds): The ratio is computed annually using end-of-year market values as reported by Statistics Sweden. 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.
Portfolio volatility	Using 12 monthly return observations, we calculate the annualized, value-weighted portfolio return volatility for each twin and year. The portfolio consists of the holdings of risky (i.e., equity) assets and is missing for individuals that do not hold risky assets.
Proportion stocks	The fraction of risky (i.e., equity) holdings invested in individual stocks as opposed to mutual funds, as reported by Statistics Sweden: This measure is computed annually and is missing for individuals that do not hold risky assets.
Participation	An annual indicator variable that equals one if *Risky share* is strictly positive and zero if *Risky share* is zero.
Risky share >0	The variable equals *Risky share* if *Risky share* is strictly positive and is missing otherwise.
Total portfolio volatility	The return volatility of the entire financial portfolio, consisting of risk-free investments, as well as risky (equity) investments: The volatility of risk-free investments is assumed to be zero. It is calculated annually using monthly return observations. It is missing for those that do not hold risky financial assets. The portfolio consists of the holdings of risky (i.e., equity) assets and is missing for individuals that do not hold risky assets.
Total proportion stocks	The fraction of all financial assets invested in individual stocks as opposed to mutual funds, as reported by Statistics Sweden. This measure is computed annually and is missing for individuals that do not hold risky assets.
Turnover	Turnover is the number of sales transactions over the course of a year relative to the number of portfolio positions at the beginning of the year.
Proportion lottery	The end-of-year proportion of risky assets invested in lottery-like assets: We define an *asset* as a lottery asset if it has a below median price, as well as above median idiosyncratic volatility and skewness. See Cronqvist and Siegel (2014) for details.
Portfolio skewness	The return skewness of the portfolio of risky financial assets: It is calculated annually using monthly return observations.
Bias index	The Bias Index summarizes the magnitude of the five investment behaviors. It takes on values between zero and 10. For each behavior, we assign a value of zero (no bias), one, or two (most biased), depending on the observed level. The index is the sum across all six investment behaviors. If for a given investor, a behavior is missing, we use the median behavior to assign the bias index component (zero, one, or two). In particular, for *Diversification*, we assign two to investors who hold 70% or more of their risky financial assets in individual stocks, one to investors who hold between 30 and 70% of their risky financial assets in individual stocks, and zero to all other investors. For *Home bias*, we assign two to investors who invest at least 80% of their risky financial portfolio in Sweden, one to investors with less than 80%, but more than 20% in Sweden, and zero to all other investors. For *Turnover*, we assign two to investors with a value above 55%, one to investors with a value between 20 and 55%, and zero otherwise. For *Performance chasing*, we assign two to investors with a value above 40%, one to investors with a value between 20 and 40%, and zero otherwise. For *Skewness preference*, we assign two to investors with a value above 15%, one to investors with a value between 5 and 15%, and zero otherwise.
Socioeconomic characteristics	
Male co-twin (F_M)	An indicator variable that is one if a female twin has a male co-twin, and zero otherwise.
Nontwin male (female) sibling	An indicator that is one if a female fraternal twin has a Male (Female) nontwin sibling, and zero otherwise.
Any male (female) sibling	An indicator that is one if a female nontwin has any male (female) siblings, and zero otherwise.

(*continued*)

Table A1
Continued

Variable	Definition
Birth weight (ln)	The natural logarithm of the birth weight (measured in grams (g)) as reported by the Swedish Twin Registry.
Net worth (ln)	The difference between the end-of-year market value of an individual's assets and her liabilities (for each year an individual is included in our sample), as reported by Statistics Sweden. We compute the natural logarithm of net worth, originally expressed in nominal Swedish Krona (SEK).
Volatility of labor income	The time-series standard deviation of the log-growth-rate of an individual's income (including income of employees and of those that are self-employed, but excluding income from capital) between 2000 and 2007 (as reported by Statistics Sweden). The variable is missing if four or more of the log growth rates are missing. The top and bottom one percentile of the log growth rate distribution is set to missing.
Business owner	An indicator that is one if in a given year an individual has income from active business activity that exceeds 50% of the labor income. The indicator is zero otherwise: Income data are from Statistics Sweden.
Years of education	*Years of education* is based on the highest completed degree. For a subset of the sample, the variable is obtained from the Swedish Twin Registry. We use a linear regression model to extend the variable to the rest of our sample. Specifically, we regress the years of education onto variables indicating the highest degree obtained (e.g., high school, college) (available for most individuals in our data set from Statistics Sweden) and then predict years of education out of sample.
Poor health	An indicator variable that equals one if in a given year an individual an individual receives payments because of illness, injury, or disability, and zero otherwise: Data on payments are obtained from Statistics Sweden.
Age	The age for every year that an individual is included in our sample. Age is obtained from the Statistics Sweden. In our analyses, we use indicator variables for those younger than 35 (*Age less than 35*), between 35 and 49 (*Age less than 50*), and between 50 and 65 (*Age less than 66*).
Male / female sibling age gap	The age difference between a female singleton and the closest (in age) male/female sibling.
Birth order	The order of birth within the family: Firstborn siblings are assigned a value equal to one. Twins are assigned the same birth order number.
Number of siblings	The number of siblings (brothers and sisters) of the twin in the family of origin: The count includes the co-twin.
Male	An indicator variable that equals one if an individual is male, and zero otherwise: Gender is obtained from Statistics Sweden.
Female	An indicator variable that equals one if an individual is female, and zero otherwise: Gender is obtained from Statistics Sweden.
Missing education data	An indicator variable that equals one if no educational data are available for an individual, and zero otherwise. Educational information is obtained from Statistics Sweden.
Single	An indicator variable that equals one if an individual is single in a given year, and zero otherwise: Marital status information is obtained from Statistics Sweden.
Divorced	An indicator variable that equals one if an individual has divorced in the past (and has not re-married since), and zero otherwise: Marital status information is obtained from Statistics Sweden.
Number of children	The number of children living in the same household in a given year: Family data are from Statistics Sweden.
Retired	An indicator variable that equals one if an individual is retired and zero otherwise: Occupational data are obtained from Statistics Sweden.
Disposable income (ln)	The natural logarithm of individual disposable income for every year that an individual is included in our sample, as defined by Statistics Sweden, that is, the sum of income from labor, business, and investment, plus received transfers, less taxes and alimony payments, originally expressed in nominal Swedish Krona (SEK): The data are obtained from Statistics Sweden.
Socioeconomic characteristics	
More contacts	An indicator variable that is one for those twin pairs with above median contact frequency and zero for those with below median contact frequency: *Contact frequency* is 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.
Shorter travel distance	An indicator variable that is one for those twins with below medain driving distance between them: Driving distance is the distance in kilometers between the municipalities of the twins' primary residence. The distance is obtained from Google Maps.
High portfolio overlap	An indicator variable that is one for those twin pairs whose portfolio overlap is 50% or larger. Portfolio overlap is the sum of the absolute value of portfolio weight differences across the two twins. This measure ranges between zero (identical portfolios) and two (nonoverlapping portfolios). A value equal to one corresponds to a 50% portfolio overlap.

Table A2
Social interactions

	Participation			Risky share > 0			Total portfolio volatility			Total proportion stocks		
	Contact frequency (1)	Travel distance (2)	Portfolio overlap (3)	Contact frequency (4)	Travel distance (5)	Portfolio overlap (6)	Contact frequency (7)	Travel distance (8)	Portfolio overlap (9)	Contact frequency (10)	Travel distance (11)	Portfolio overlap (12)
Male co-twin (F_M)	2.206**	0.682	1.152**	0.733	1.258**	0.993**	0.149	0.300**	0.407***	−0.301	1.623	1.989***
	(0.030)	(0.368)	(0.048)	(0.322)	(0.034)	(0.030)	(0.497)	(0.048)	(0.002)	(0.827)	(0.119)	(0.009)
More contacts	−0.718			−0.020			−0.359*			−3.106**		
	(0.473)			(0.979)			(0.055)			(0.013)		
More contacts $\times F_M$	−3.221**			−0.014			0.121			2.510		
	(0.014)			(0.988)			(0.653)			(0.148)		
Shorter travel distance		−2.596***			−0.051			−0.427***			−2.508**	
		(0.001)			(0.940)			(0.005)			(0.026)	
Shorter travel distance $\times F_M$		−0.010			−1.114			−0.014			0.138	
		(0.993)			(0.242)			(0.958)			(0.926)	
High portfolio overlap			26.083***			3.677**			2.161***			15.802***
			(0.000)			(0.038)			(0.000)			(0.000)
High portfolio overlap $\times F_M$			−0.790			−3.455**			−1.010**			0.588
			(0.227)			(0.029)			(0.033)			(0.819)
Additional controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	124,141	124,141	124,141	91,522	91,522	91,522	54,893	54,893	54,893	91,522	91,522	91,522
R-squared	0.014	0.014	0.028	0.001	0.001	0.001	0.003	0.003	0.003	0.001	0.001	0.002

Table A2 extends the analysis performed in Table 5 to additional outcomes. We use a Tobil model in all cases except for Columns (1) to (3) where we use a linear probability model. For each model, we report the coefficient estimates, as well as the corresponding p-values. p-values are based on double-clustered standard errors, robust for correlation across years within same individuals and across individuals within the same year. All variables are defined in detail in Table A1. N provides the number of observations used in each estimation. *R-squared* denotes the *pseudo R-squared*, except for Columns (1) to (3) where it denotes the coefficient of determination. Levels of significance are denoted as follows: * if $p < 0.10$; ** if $p < 0.05$; *** if $p < 0.01$.

Table A3
The effect of having male siblings

Panel A: Families of firstborn female singletons and same-sex fraternal twins

	Participation		Risky share > 0		Total portfolio volatility		Total proportion stocks	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Male sibling	−2.039	−4.285	2.337	0.934	−0.004	0.066	−3.858	1.746
	(0.399)	(0.413)	(0.276)	(0.825)	(0.995)	(0.957)	(0.348)	(0.840)
Male sibling age gap		0.052		1.366**		0.179		−1.318
		(0.949)		(0.032)		(0.323)		(0.346)
Female sibling age gap		−0.475		1.035*		0.195		0.011
		(0.487)		(0.079)		(0.289)		(0.993)
Additional controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	5,624	5,624	4,449	4,449	2,608	2,608	4,449	4,449
R-squared	0.002	0.003	0.002	0.002	0.002	0.002	0.000	0.000
Panel B: All families								
Male sibling	−0.099	−0.823	1.064*	0.750	0.221	0.056	0.921	0.937
	(0.893)	(0.354)	(0.079)	(0.315)	(0.203)	(0.789)	(0.430)	(0.513)
Male sibling age gap		0.141		0.076		0.031		−0.026
		(0.256)		(0.404)		(0.192)		(0.881)
Female sibling age gap		−0.127		0.062		−0.035		−0.159
		(0.160)		(0.420)		(0.169)		(0.293)
Additional controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	133,560	133,560	99,477	99,477	60,139	60,139	99,477	99,477
R-squared	0.005	0.005	0.003	0.003	0.003	0.003	0.001	0.001

Table A3 extends the analysis performed in Table 6 to additional outcomes. We use a Tobit model in all cases except for Columns (1) to (2) in each Panel where we use a linear probability model. For each model, we report the coefficient estimates, as well as the corresponding p-values. p-values are based on double-clustered standard errors, robust for correlation across years within same individuals and across individuals within the same year. All variables are defined in detail in Table A1. N provides the number of observations used in each estimation. *R-squared* denotes the *pseudo R-squared*, except for Columns (1) to (2) in each Panel where it denotes the coefficient of determination. Levels of significance are denoted as follows: * if $p < 0.10$; ** if $p < 0.05$; *** if $p < 0.01$.

Table A4
Probability of having a male co-twin and parental characteristics

	$\Pr(I^{FM})$ Mother's characteristics			$\Pr(I^{FM})$ Father's characteristics			$\Pr(I^{FM})$ Parental characteristics	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mother's age at birth	−0.032	−0.078	−0.049				0.023	0.020
	(0.825)	(0.642)	(0.773)				(0.942)	(0.949)
Mother's years of education	−0.793**	−0.726**	−0.699*				−0.573	−0.456
	(0.027)	(0.045)	(0.057)				(0.197)	(0.313)
Mother's missing education data	0.911	1.526	1.223				−2.723	−1.691
	(0.820)	(0.706)	(0.766)				(0.614)	(0.758)
Father's age at birth				−0.201	−0.142	−0.196	−0.049	−0.128
				(0.207)	(0.435)	(0.286)	(0.858)	(0.644)
Father's years of education				−0.337	−0.329	−0.255	−0.268	−0.229
				(0.384)	(0.396)	(0.513)	(0.553)	(0.618)
Father's missing education data				4.227	3.961	4.689	2.000	3.044
				(0.341)	(0.375)	(0.298)	(0.709)	(0.574)
Additional controls	No	Yes	Yes	No	Yes	Yes	Yes	Yes
Birthplace fixed effects	No	No	Yes	No	No	Yes	No	Yes
N	7,003	7,003	7,003	4,998	4,998	4,998	4,126	4,126
R-squared	0.009	0.009	0.025	0.006	0.006	0.033	0.006	0.034

Table A4 reports results from cross-sectional linear probability models (OLS) regressions of an indicator variable (I^{FM}) equal to one if the female twin has a a male co-twin onto parental characteristics, likely predetermined at the twins' birth. The sample includes only female fraternal twins. Coefficient as expressed as percentage points variation in the probability of having a male co-twin. Additional controls are: birth order of the twins and number of siblings. *Birthplace fixed effects* are based on the county of birth of the twins. For each model, we report the coefficient estimates as well as the corresponding p-values. p-values are based on clustered standard errors, robust for correlation across twins within the same family. More details on these variables are in Table A1. N provides the number of observations used in each estimation. Levels of significance are denoted as follows: * if $p<0.10$; ** if $p<0.05$; *** if $p<0.01$.

Table A5
Controlling for socioeconomic characsteristics

	Risky Share (1)	Participation (2)	Risky share > 0 (3)	Portfolio volatility (4)	Total portfolio volatility (5)	Proportion stocks (6)	Total proportion stocks (7)
Male co-twin (F_M)	0.792	0.183	0.808*	0.285**	0.233**	2.711**	1.625**
	(0.187)	(0.737)	(0.055)	(0.041)	(0.033)	(0.021)	(0.025)
Net worth (ln)	1.432***	4.817***	−4.148***	−0.030	−0.547***	7.487***	3.787***
	(0.000)	(0.000)	(0.000)	(0.916)	(0.000)	(0.000)	(0.000)
Volatility of labor income	−0.080***	−0.000	−0.099***	0.016***	−0.000	0.520***	0.302***
	(0.001)	(0.993)	(0.000)	(0.004)	(0.999)	(0.000)	(0.000)
Business owner	−2.569	3.068	−6.729***	0.452	−0.380	17.968***	8.670***
	(0.212)	(0.126)	(0.000)	(0.397)	(0.433)	(0.000)	(0.000)
Years of education	0.993***	0.809***	0.343***	0.166***	0.149***	1.272***	1.052***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Missing education data	0.000	−2.143	3.477***	0.309	0.686***	11.873***	9.756***
	(1.000)	(0.138)	(0.001)	(0.372)	(0.010)	(0.000)	(0.000)
Poor health	−3.968***	−4.179***	−0.252	−0.210	−0.100	−3.224***	−2.254***
	(0.000)	(0.000)	(0.536)	(0.130)	(0.360)	(0.004)	(0.001)
Single	−0.290	1.004	−1.595***	−1.235***	−0.851***	−4.220***	−2.839***
	(0.721)	(0.202)	(0.005)	(0.000)	(0.000)	(0.009)	(0.005)
Divorced	−2.237**	−1.521*	−0.987	−0.761***	−0.360**	−3.978**	−2.167*
	(0.015)	(0.085)	(0.123)	(0.000)	(0.032)	(0.026)	(0.055)
Number of children	1.677***	−0.385	2.387***	0.130**	0.484***	−0.111	0.536
	(0.000)	(0.186)	(0.000)	(0.049)	(0.000)	(0.854)	(0.170)
Retired	−1.818***	−1.070	−0.643	0.079	−0.067	−0.126	−0.155
	(0.010)	(0.276)	(0.236)	(0.666)	(0.644)	(0.924)	(0.851)
Disposable income (ln)	−1.944***	2.037*	−4.481***	−0.451***	−0.810***	8.876***	4.164***
	(0.000)	(0.082)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)
Additional controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Birthplace fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	124,132	124,132	91,522	54,887	54,887	91,522	91,522
R-squared	0.031	0.059	0.064	0.030	0.046	0.039	0.030

Table A5 reports results from Tobit regressions of annual measures of financial risk taking of female fraternal twins between 1999 and 2007 onto an indicator variable for women with a male co-twin ("Male co-twin"), as well as a large set of socioecnomic characteristics. In Column 2, we use instead a linear probability model (OLS). Additional controls are the same control variables used in Table 3. *Birthplace fixed effects* are based on the county of birth of the twins. For each model, we report the coefficient estimates, as well as the corresponding p-values. p-values are based on double-clustered standard errors, robust for correlation across years within same individuals and across individuals within the same year. All variables are defined in detail in Table A1. *N* provides the number of observations used in each estimation. *R-squared* denotes the *pseudo R-squared*. Levels of significance are denoted as follows: * if $p<0.10$; ** if $p<0.05$; *** if $p<0.01$.

Table A6
Direct effect of birth weight

	Risky share (1)	Participation (2)	Risky share > 0 (3)	Portfolio volatility (4)	Total portfolio volatility (5)	Proportion stocks (6)	Total proportion stocks (7)
Birth weight (ln)	5.920*	8.208*	5.183	−3.272***	−1.924*	−13.267***	−5.605*
	(0.078)	(0.051)	(0.132)	(0.002)	(0.091)	(0.005)	(0.051)
Net worth (ln)	−1.201***	2.650***	−2.818***	−0.064	−0.368*	1.724***	0.782*
	(0.038)	(0.000)	(0.000)	(0.885)	(0.352)	(0.001)	(0.092)
Volatility of labor income	0.901	−1.313	−0.872	4.935*	−0.548	26.554***	12.019**
	(0.903)	(0.876)	(0.914)	(0.112)	(0.847)	(0.002)	(0.041)
Business owner	−3.295	1.262	−4.571	−1.541	−2.809***	7.880	4.369
	(0.398)	(0.437)	(0.326)	(0.232)	(0.002)	(0.099)	(0.145)
Years of education	0.186	0.013	0.394	−0.032	−0.022	−0.214	−0.117
	(0.535)	(0.965)	(0.234)	(0.810)	(0.845)	(0.586)	(0.665)
Missing education data	−6.709*	−8.526**	−0.629	0.513	−1.082	−4.393	−3.425
	(0.104)	(0.088)	(0.873)	(0.846)	(0.576)	(0.360)	(0.293)
Poor health	0.510	−0.013	1.179	−0.711	0.016	0.712	0.717
	(0.494)	(0.989)	(0.302)	(0.444)	(0.970)	(0.533)	(0.380)
Single	1.168	3.273	−1.098	−2.787***	−2.861***	−3.432	−2.608
	(0.567)	(0.147)	(0.567)	(0.000)	(0.005)	(0.214)	(0.212)
Divorced	−0.305	−6.890***	3.195*	−1.138	0.101	−4.486*	−0.905
	(0.857)	(0.000)	(0.084)	(0.239)	(0.826)	(0.062)	(0.535)
Number of children	−0.105	−0.851	−0.615	0.235	−0.188	0.672	0.168
	(0.916)	(0.355)	(0.477)	(0.601)	(0.537)	(0.377)	(0.791)
Retired	−4.877***	−3.939***	−3.155**	0.618	0.064	2.905*	0.589
	(0.004)	(0.008)	(0.085)	(0.441)	(0.922)	(0.058)	(0.611)
Disposable income (ln)	−5.127***	−0.544	−6.195***	−2.339***	−2.377***	0.578	−1.584
	(0.004)	(0.761)	(0.000)	(0.038)	(0.002)	(0.659)	(0.159)
Twin-pair fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	15,767	15,767	10,754	4,497	4,497	10,754	10,754
R-squared	0.452	0.475	0.433	0.489	0.489	0.605	0.555

Table A6 reports results from linear regressions of annual measures of financial risk taking of identical twins between 1999 and 2007 onto birth weight (*Birth weight (ln)*), a large set of socioeconomic controls, and twin-pair fixed effects. For each model, we report the coefficient estimates, as well as the corresponding p-values. p-values are based on double-clustered standard errors, robust for correlation across years within same individuals and across individuals within the same year. All variables are defined in detail in Table A1. N provides the number of observations used in each estimation. *R-squared* denotes the coefficient of determination. Levels of significance are denoted as follows: * if $p < 0.10$; ** if $p < 0.05$; *** if $p < 0.01$.

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