

The Evolutionary Basis of Sex Differences
in Financial Risk Preferences

Abstract

Women take less financial risk than men, which is thought to explain part of the gender gap in the workplace, since financial risk preferences correlate with wages and selection into male dominated occupations. In this review, we suggest that sex differences in financial risk preferences have an evolutionary basis. We summarize a well-accepted theory that explains analogous sex differences in non-human animals, for traits such as showiness, aggression, territoriality, weaponry, and ostentatious displays. We briefly review some of the overwhelming evidence from animals that supports this theory. We also review select evidence for related sex differences in humans, including aggression, violence, and sensation seeking. Finally, we summarize the growing body of evidence correlating financial risk preferences with measures of sex hormones, namely, circulating testosterone, the ratio of individuals' second to fourth digit (2D:4D), left handedness, and facial masculinity. In the conclusion, we address potential misunderstandings, provide some novel predictions, and discuss significant policy implications which we believe cannot be ignored by anyone interested in ameliorating the gender gap in the workplace.

Keywords: risk, sex differences, financial gambles, evolution, testosterone

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Women take less financial risk than men (for a review, see Croson & Gneezy, 2009), which may partly explain the gender gap in the workplace, since financial risk preference correlate with wages and selection into male-dominated occupations (Barsky, Kimball, & Shapiro, 1997; Bonin, Dohmen, Falk, Huffman, & Sunde, 2007; Dohmen et al., 2009) and entrepreneurship (Elston, Harrison, & Rutström, 2005). Understanding and addressing this gender gap is a major policy goal (*2012 Democratic National Platform: Moving America Forward*, 2012). In this paper, we summarize the logic and evidence for an evolutionary basis for observed differences in financial risk preferences between men and women.

This argument is several-fold. First, we summarize a well-accepted theory that explains analogous sex differences in non-human animals, for traits such as showiness, aggression, territoriality, weaponry, and ostentatious displays (Bateman, 1948; Trivers, 1972). Second, we briefly review some of the overwhelming evidence from animals that supports this theory. Third, we review select evidence for related sex differences in humans in domains other than financial risk preferences, such as aggression, violence, and sensation seeking.

Finally, we summarize the growing body of evidence correlating financial risk preferences with measures of sex hormones, namely, circulating testosterone, the ratio of individuals' second to fourth digit (2D:4D), left handedness, and facial masculinity. Where possible, we summarize the results of these studies using meta-analyses. We find a significant correlation in all four literatures.

In the conclusion, we address potential misunderstandings, provide some novel predictions, and discuss significant policy implications which we believe cannot be ignored by anyone interested in ameliorating the gender gap in the workplace.

This paper builds on the existing literature by emphasizing *financial* risk preferences. Financial risk preferences refer to subjects' willingness to accept higher *variance* in monetary payoffs in order to achieve higher *expected* monetary payoffs. These preferences are typically

assessed by observing how subjects allocate money across different lotteries (Gneezy & Potters, 1997; Holt & Laury, 2002; Eckel & Grossman, 2002). An exemplifying measure is Gneezy and Potters (1997), in which subjects are given a fixed amount of money to allocate between a sure thing and a risky coin toss. Whatever they allocate to the coin toss is multiplied by 2.5 if the coin lands on heads, and 0 if it lands on tails. Subjects who allocate more money to the coin-toss are said to be more risk-taking since they are increasing the variance in their earnings while increasing their expected earnings.

Measures of financial risk preferences have been shown to correlate with health risks such as drinking and smoking (Anderson & Mellor, 2008; Lusk & Coble, 2005; C. W. Lejuez et al., 2002; C. Lejuez, Aklin, Zvolensky, & Pedulla, 2003; C. Lejuez, Aklin, Jones, et al., 2003), and, as mentioned earlier, with labor market outcomes. Financial risk preferences correspond closely to the predictions of the theory and provide an internally valid test of its predictions. They also provide pertinent insight for addressing the gender gap in the workplace.

Evolutionary Theory

We start by explaining the theory (Bateman, 1948; Trivers, 1972) as it applies to animal analogs of risk preferences, such as aggression and weaponry, then extend the argument to risk preferences.

Males typically invest less in parenting, e.g., gestation, brooding, and lactation. Consequently, the number of offspring a male has is constrained primarily by the number of mates he accrues. To see the logic, consider the extreme case where males do none of the parenting. Then, the number of offspring a male has increases almost proportionally with the number of mates he has (Bateman, 1948). In contrast, the number of offspring a female has will be largely constrained by the resources she accrues, but be largely unaffected by increased mating opportunities.

The number of offspring a male has therefore depends more on his ability to outcompete other males in obtaining mates. This explains why males would be more aggressive and invest

more in weaponry and ostentatious display (Trivers, 1972). Again, to see the logic, consider the case of the elephant seal, in which a single "alpha" male mates with a harem of 30-100 females, and can have up to 500 offspring. Non-alpha males mate with almost no females, and it is easy to understand why non-alpha males fight, sometimes to death, to beat out the incumbent alpha male. Like a hockey team that is down 3-0 in the Third and pulls the goalie, the non-alpha male has little to lose and everything to gain from going "all in" in combat.

The theory extends to risk preferences (Robson, 1996; E. Dekel & Schochter, 1999; Daly & Wilson, 2001). The intuition is as follows. Consider the relationship between resources and offspring for males. Males who have few resources have about as many offspring as males who have average levels of resources; in extreme cases, such as in the elephant seal, they each have no offspring because neither becomes the alpha. Whereas males with high levels of resources have many more offspring. That is, males' reproduction is convex in resources. This implies that males who take on fair gambles will increase their expected number of offspring. Just as in combat, the non-alpha male has little to lose and everything to gain from going all in. In contrast, females with low levels of resources do have fewer offspring than those with average resources, and those with abundant resources have not much more. That is, females' reproduction is concave in resources, and hence females who take fair gambles will decrease their expected number of offspring. Of course, it need not be the case that males' reproduction is actually convex and that males benefit from fair gambles, or that females' reproduction is concave and they are harmed by gambles—it just needs to be the case that males' reproductive success is more convex than females' for males to benefit more from gambles than females.

To see how the difference in risk preferences might evolve, consider a gene that is activated by testosterone exposure and reduces anxiety induced by possible losses from risky gamble. Such a gene would be likely to spread because those who carry the gene will have male offspring who take gambles and female offspring who do not.

The above theory has several advantages. First, it suggests novel predictions about sex differences that one would not predict in the absence of the theory: sex differences will reverse in

species where males invest more in parenting, and will be exacerbated in species where sex differences in parenting are larger, as in polygynous species. These predictions bear out empirically, as discussed in the next section. Second, these predictions are falsifiable. For example, if the sex difference in aggression were uncorrelated with or decreased with degree of polygyny, one would conclude that the theory were false. Third, one could not easily contrive an evolutionary theory that predicts the opposite result; it would be extremely hard to proffer an evolutionary justification for lower male aggression, under the typical circumstances where males invest less in parenting. Finally, the theory does not rely on assumptions about the early hominoid environment, and is general to all sexually reproducing species.

The theory can only explain sex differences in risk preferences if it is indeed the case that human males invest less in parenting and display a high degree of polygyny. We now confirm these conditions hold (for a review, see Carl, 2012). Based on measures of sexual dimorphism which covary with polygyny across primate species, humans are thought to have evolved in mildly polygamous mating systems for long periods of their evolutionary history (Daly & Wilson, 1988a; Plavcan, 2001; Alexander, Hoogland, Howard, Noonan, & Sherman, 1979). Moreover, human males have higher reproductive potential than females as evidenced by some extreme examples: about eight percent of Asian males are descended from a single male—likely, Genghis Kahn (Zerjal et al., 2003), and Solomon purportedly had 800 wives. More generally, variance in reproductive success has been shown to be consistently higher for males than females. For example, the ratio of male variance to female variance is 3.1 for the Brazilian Xente Indians (Salzano, Weinstein, & Neel, 1967), 1.77 for the Dobe !Kung (Howell, 1979), between 2.02 and 4.69 for the Yanomoamo (Chagnon, 1979), and 2.76 for the Aka pygmies (Hewlett, 1988). Finally, recent experimental evidence supports the hypothesis that human risk preferences function to promote increased peer and reproductive success (Hill & Buss, 2010; Baker Jr & Maner, 2008; Pawlowski, Atwal, & Dunbar, 2008; Wang, Kruger, & Wilke, 2009).

Select Evidence from Animals

Consistent with the theory presented above, sex differences in showiness, aggression, territoriality, and weaponry are ubiquitous in the animal kingdom (for a review, see Andersson, 1994). For instance, among the 113 bird species with spurs—a sharp spike grown on the leg—both sexes have them in 16 species, males alone have them in 97, but females alone have them in none.

Animal evidence also provides uncanny support for the two falsifiable tests suggested by the theory. The first prediction we address is that sex differences will reverse in species where males invest more in parenting. There are 23 exceptional species in which females are showier, more aggressive, more territorial, and have bigger weapons. These exceptions support the theory, since for 21 out of 23 of these species, male parental investment is greater than females'. Examples include phalaropes (Hohn, 1967), Pipefish (Svensson, 1988), and Mormon crickets (D. Gwynne, 1984). Even the two exceptions to the exceptions support the theory. For these two cases—the three spined stickleback and the Rhea Americana (T. Clutton-Brock & Vincent, 1991)—males do more parenting on average, but the marginal cost of parenting is lower for males than for females, and marginal cost is actually what matters for the theory.

The second prediction we address is that sex differences are exacerbated in species where sex differences in parenting are larger, as is the case with highly polygynous species like elephant seals. For example, in a study of 65 species of birds, sex differences in tail-length, a measure of sexual display, are larger among polygamous species than monogamous ones (Bjorklund, 1990), and among 24 species of Cervidae deer, male antlers are longer when breeding groups are larger, even after controlling for body size (S. D. Clutton-Brock & Albon, 1985).

We even see that when sex differences in parenting vary within a species, sex differences in parenting covary with sex differences in aggression and mate guarding. In Mormon crickets, parental investment depends on population density (D. T. Gwynne, 1982). In high densities, male parental investment is higher, and, as predicted, females display higher levels of aggression and mate guarding. This role reversal can even be experimentally induced by manipulating crickets' population density (D. T. Gwynne & Simmons, 1990).

Select Evidence from Humans in Domains Other Than Financial Risk Preferences

We now briefly summarize evidence from humans in domains other than financial risk preferences. As in non-human animals, human males are more aggressive than females (Daly & Wilson, 1988b, 1988a; Wilson & Daly, 1985; Daly & Wilson, 2001; Archer, 2004, 2009), and there is evidence for an evolutionary basis for this difference. For example, sex differences in aggression are greatest during reproductive age (Daly & Wilson, 1988b, 2001; Archer, 2009), and in environments with more income inequality, in which success is more variable and low-status men have more to gain (Daly & Wilson, 1988a; Wilson & Daly, 1985; Daly & Wilson, 2001). Aggression also varies with circulating testosterone (Book, Starzyk, & Quinsey, 2001). For a justification of methods which use circulating testosterone and other sex hormones to establish an evolutionary basis, see the next section.

In addition to aggression, there are well-documented sex differences in dominance (Mazur & Booth, 1998), status seeking (Kemper, 1990; Mazur & Booth, 1998), sensation seeking (e.g., Campbell et al., 2009; Roberti, 2004), promiscuous and unprotected sex, and smoking (for a review, see Byrnes, Miller, & Schafer, 1999). Again, there is evidence for an evolutionary basis for these sex differences: as with aggression, sex differences in these behaviors are greatest during reproductive age (Byrnes et al., 1999), and these behaviors correlate with measures of circulating testosterone and prenatal and pubertal sex hormones (Roberti, 2004; Campbell et al., 2010).

Evidence for an Evolutionary Basis of Financial Risk Preferences

We summarize a growing body of evidence that directly examines the evolutionary basis of sex differences in human financial risk preferences, as measured by incentivized laboratory experiments. In humans, it is difficult to demonstrate an evolutionary basis for sex differences in financial risk preferences, because it is not possible to design practical and ethical experiments that hold constant environmental influences while manipulating biology. In animals, such controlled experiments are implemented via castration or testosterone injections, but these manipulations are not feasible in humans. Further, twin and genetic studies (Cesarini, Dawes,

Johannesson, Lichtenstein, & Wallace, 2009; Dreber, von Essen, & Ranehill, 2011) cannot address sex differences. In light of these constraints, the literature has relied on studies that correlate sex hormones, such as testosterone, with measures of financial risk preferences.

Testosterone is the natural candidate for studying the evolutionary basis of sex differences in risk preferences, because it and related sex hormones are the primary mediators of all evolved sex differences in animals. Sex hormones' role in mediating sex differences is ancient and universal: they even play a role in species where sex is not chromosomally determined such as snapping turtles (Rhen & Lang, 1995), or where sex changes with age (Cardwell & Liley, 1991). Sex hormones mediate all sex differences that have been studied that have an evolutionary basis, including physical ones such as development of genitalia (Phoenix, Goy, & Gerall, 1959; Lillie, 1917) and behavioral ones such as animal aggression (Nelson, 2005). Many of the human studies referenced in the previous section also correlate sex differences with measures of testosterone in order to show an evolutionary basis.

If sex differences in risk preferences have an evolutionary basis, a first prediction is thus that circulating testosterone ought to correlate with financial risk preferences within each sex. The first subsection presents evidence in favor of such a correlation. We summarize the evidence in a meta-analysis, which finds the relationship to be statistically significant and large relative to other documented relationships with financial risk preferences. While this relationship is consistent with an evolutionary basis for sex differences in risk preferences, it provides imperfect evidence because immediate environmental factors have been shown to impact circulating testosterone (e.g., Roney et al. 2007). Thus, even if sex differences have no evolutionary basis, environmental influences could contribute to the sex differences in circulating testosterone that in turn contribute to sex differences in financial risk preferences.

One way to address this limitation is to investigate sex hormone levels during earlier stages of development, before environmental influences can play a role. Ideally, one would study this directly by correlating sex hormones levels in the womb with financial risk preferences in maturity. However, this approach would be prohibitively long and costly, so the literature employs

proxies that are easily measured in adulthood but are at least partially determined by prenatal or pubertal hormones and are not influenced by experiences thereafter. So far, three such proxies have been employed: 2D:4D and handedness, which are determined prenatally, and facial masculinity, which is determined during puberty. We review the relationships between each of these proxies and financial risk preferences in separate subsections below.

Circulating Testosterone

We begin by presenting evidence of the correlation between circulating testosterone and financial risk preferences. We identified four papers which correlate clinical measures of circulating testosterone levels with measures of financial risk preferences. These are described in Table 1. Three of the studies find a positive, statistically significant relationship, and the fourth finds a positive, statistically insignificant relationship. To facilitate comparison and aggregation of this evidence, we performed a meta-analysis, standardizing the results of each of the papers and combining them into a single estimate of the relationship between circulating testosterone and financial risk preferences in the literature.

We identified the four candidates for the meta-analysis by entering the search terms, “((risk preferences) or (risk aversion) or (risk preference)) and (circulating testosterone)” in <http://scholar.google.com> on June 15th 2012, and restricting to papers for which the measure of risk related to a trade off between expected money versus variance in money, in the laboratory or in real-world financial markets. For each study, we identified the coefficient when the risk measure was regressed on subjects’ circulating testosterone level.¹ We then normalized these coefficients by dividing by the standard deviation of the risk measure and multiplying by the standard deviation of the testosterone measure, so that each coefficient can be interpreted as the estimated effect of a standard deviation increase in circulating testosterone, in standard deviations of the risk measure. We likewise normalized the standard errors.

We then ran the two most-often used meta-analysis regressions, random effects and fixed effect meta-analysis (for more information, see Borenstein, Hedges, Higgins, & Rothstein, 2009),

to combine these estimates into a single estimated effect. Figure 1 presents the results. Regardless of the technique we use, we find a significant relationship between financial risk preferences and circulating testosterone ($p < .01$). The summary effect from random effects meta-analysis is 0.13; that is, on average, a one standard deviation increase in circulating testosterone is associated with a 0.13 standard deviation increase in the risk preference. Thus, consistent with predictions, humans with more circulating testosterone take more risks. However, because circulating testosterone can be impacted by environmental factors, we next consider proxies for sex hormone levels at earlier stages of development.

2D:4D

The first proxy for prenatal sex hormones that we consider is the ratio between the second and fourth digits, 2D:4D, which is also known as the digit ratio (Manning, Scutt, Wilson, & Lewis-Jones, 1998). Higher prenatal exposure to male sex hormones is hypothesized to lead to lower 2D:4D due to differential susceptibility of the fingers to male sex hormones that trigger growth (McIntyre, 2006). One study finds a 20% correlation between 2D:4D and the amniotic testosterone-to-estradiol ratio (Lutchmaya, Baron-Cohen, Raggatt, Knickmeyer, & Manning, 2004). Another finds that individuals with abnormally high in-utero exposure to male sex hormones have lower 2D:4D (Brown, Hines, Fane, & Breedlove, 2002), and a third finds that individuals with less sensitivity to testosterone have lower 2D:4D (Manning, Bundred, Newton, & Flanagan, 2003). Additionally, there is indirect evidence for the relationship between 2D:4D and prenatal sex hormones. 2D:4D is lower in men than in women in all populations investigated to date (Manning, 2002). Additionally, a number of studies find that 2D:4D correlates negatively with masculinization on a wide variety of sexually dimorphic traits, including competitiveness, athleticism, and performance in a mental rotation task (Honekopp, Rudolph, Beier, Liebert, & Muller, 2006; Manning & Taylor, 2001).

However, 2D:4D is also hypothesized to be a relatively weak proxy for prenatal sex hormone levels. First, the correlation with prenatal sex hormones is only 20% (Lutchmaya et al.,

2004). Additionally, differences in 2D:4D between ethnic groups, even between Caucasians from different European origins, is larger than the variation between sexes within an ethnic group (Manning, Stewart, Bundred, & Trivers, 2004). Moreover, the overlap between the distribution of 2D:4D by sex is 60%, and the correlation with sexually dimorphic traits is rather weak (McIntyre, 2006). Consistent with this observation, many studies correlating 2D:4D with measures besides financial risk preferences have found null results.

Likewise, the results from different papers that have correlated 2D:4D with measures of financial risk preferences, are, *prima facie*, inconclusive. Some papers document a statistically significant relationship between 2D:4D and financial risk preferences in the predicted direction, some document a statistically insignificant relationship in the predicted direction, and some even document a statistically insignificant relationship in the opposite direction. To facilitate comparison and aggregation of this evidence, we performed a meta-analysis, standardizing the results of each of the papers and combining them into a single estimate of the relationship between 2D:4D and financial risk preferences in the literature.

We identified candidates for the meta-analysis by entering the search terms, "(risk preferences) or (risk aversion) or (risk preference)) and (2D:4D) or (2D4D) or (digit ratio) or (digit ratios) or (D2:D4) or (D2D4))" in <http://scholar.google.com> on May 6th 2012. Again, we restricted to papers for which the measure of risk related to a trade off between expected money versus variance in money. We identified a total of nine papers for inclusion in the meta-analysis. These are described in Table 2.

For each study, we identified the coefficient when the risk measure was regressed on subjects' 2D:4D ratio, then employed the same methodology described in the previous subsection. Figure 2 presents the results. Regardless of whether we employ random effects or fixed effects meta-analysis, we find a significant effect of 2D:4D ($p < .01$). The summary effect from random effects meta-analysis is 0.11; that is, on average, a one standard deviation increase in 2D:4D is associated with a 0.11 standard deviation increase in the risk preference. Since 2D:4D is a weak proxy for prenatal sex hormone levels, we suggest that this coefficient may be a substantial

understatement of the relationship between prenatal circulating testosterone levels and financial risk preferences. We also emphasize the importance of aggregating results across studies when considering noisy measures such as 2D: 4D. Our meta-analysis suggests that there is a true relationship between 2D:4D and financial risk preferences, but because 2D:4D is a noisy measure, we should expect many individual studies to yield null results or even insignificant results in the opposite direction.

Handedness and Footedness

The second proxy for prenatal sex hormones that we consider is handedness and footedness, or whether an individual prefers to use his or her left or right hand and foot. Like 2D:4D, these traits are thought to be a proxy for prenatal exposure to sex hormones. Evidence suggests that women who are exposed to synthetic estrogen prenatally are more likely to be left handed than their unexposed sisters (Smith & Hines, 2000). Handedness can be influenced by experiences, as individuals may be taught to use their other hand, but evidence suggests that footedness does not change in such cases (Porac, Coren, & Searleman, 1986; Teng, Lee, Yang, & Chang, 1976; Annett, 1970). There is also indirect evidence that prenatal sex hormones contribute to left handedness. In every culture studied, males are more likely to be left handed (Halpern, 2000). A number of studies have found that left-handed individuals are more masculinized on various sexually dimorphic traits, ranging from spatial abilities (Porac & Coren, 1981) to success in architectural school (Peterson & Lansky, 1974). Handedness differences in the workplace also mimic sex differences: left-handed individuals earn higher wages, and over-represented in the sciences, and in the highest echelons of corporate management and government (Porac & Coren, 1981; Ruebeck, Jr., & Moffit, 2007).

To our knowledge, there is a single, unpublished study correlating handedness and footedness with financial risk preferences (Hoffman & Gneezy, 2010). The study employed the Gneezy and Potters (1997) lottery task to measure financial risk preferences, which was correlated with subjects' handedness. There were 2,000 subjects. Of these, 1,207 were female

and 792 were male, 1,416 were right handed and 258 were left handed. Consistent with previous studies (Croson & Gneezy, 2009), men risked more than women: the average investment from men was \$125.27 and \$98.61 for women. Also consistent with previous studies, there were more lefty males than females: 18.9% of males were lefty and 15.4% of females were lefty.

Within each sex, the average amount invested was higher for lefties than righties: the average investment for righty females was \$96.90, compared to \$108.90 for lefty females. The average for righty males was \$124.70, compared to \$128.20 for lefty males. Regressing the amount invested on sex, handedness and linear and quadratic terms for age, income, and education, the sex coefficient is \$27.08, and the lefty coefficient is \$9.65 ($p = .05$). The authors also found an equally strong relationship between left footedness and financial risk preferences. The magnitude of the relationship between handedness and financial risk preferences is large relative to differences in risk-taking between men and women. Moreover, it likely underestimates the effect of prenatal sex hormones on financial risk preferences since handedness is only a proxy for prenatal sex hormone levels.

Facial Masculinity

The final proxy we consider is facial masculinity. Facial masculinity is thought to be a marker for sex hormone exposure during puberty (Johnston, Hagel, Franklin, Fink, & Grammer, 2001). Indeed, only after puberty is sexual dimorphism in human facial masculinity noticeable. Thus, while environmental influences before puberty can influence pubertal sex hormone levels and thus facial masculinity, the impact of environmental influences on facial masculinization should be smaller than the impact of environmental influences on circulating testosterone. Vanderschueren and Bouillon (1995) suggest that testosterone during human male puberty facilitates the growth of bones by increasing outside bone diameter and bone mass, thus influencing craniofacial growth and facial masculinity. Consistent with this hypothesis, Verdonck, Gaethofs, Carels, and de Zegher (1999) find that, among delayed puberty boys, providing low doses of testosterone over a period of one year significantly increases development in measured

facial masculinity, relative to a control group. Additionally, there is indirect evidence that sex hormones influence facial masculinity: Carre (2009) find that facial masculinity correlates positively with aggression. However, like 2D:4D, facial masculinity is hypothesized to be a weak proxy for sex hormone levels, in this case, in puberty rather than in the womb. However, the exact correlation between pubertal sex hormones and facial masculinity is unknown.

Commonly used measures of facial masculinity are cheekbone prominence, jaw height/lower face height, lower face height/face height, and face width/lower face height. Previous studies have found that the identification of these measures is reliable (Grammer & Thornhill, 1994; Scheib, Gangestad, & Thornhill, 1999). These four measures of facial masculinity are sexually dimorphic.

We are aware of one study that correlates facial masculinity with financial risk preferences (Apicella et al., 2008). In order to measure facial masculinity, Apicella et al. (2008) took photos of subjects' face while subjects looked into the camera with neutral expressions. To control for size, they standardized the faces so that the distance between subjects' pupils is the same, then input the faces into software called Psychomorph,² which measures cheekbone prominence, jaw height/lower face height, lower face height/face height, and face width/lower face height. Finally, they combine these into a single measure of facial masculinity which is correlated with subjects' investment choices in the Gneezy and Potters (1997) lottery task.

When controlling for circulating testosterone, Apicella et al. (2008) find that men with a one standard deviation increase in facial masculinity invested six percentage points more in the Gneezy and Potters (1997) lottery task ($p < .01$).

Conclusion

In this review, we suggest that men evolved to take more financial risk than women. We summarize a well-accepted theory that explains analogous sex differences in non-human animals. We briefly review some of the overwhelming evidence from animals that supports this theory. Then, we review evidence for related sex differences in humans, including aggression, violence,

and sensation seeking. Finally, we summarize the growing body of evidence correlating financial risk preferences with measures of sex hormones, namely, circulating testosterone, the ratio of individuals' second to fourth digit (2D:4D), left handedness, and facial masculinity. We find a significant correlation in all four literatures. The theory and combined evidence strongly support an evolutionary basis for sex differences in financial risk preferences. We now address potential misunderstandings, provide some novel predictions, and discuss significant policy implications.

Potential Misunderstandings

We are concerned that readers might conclude that sex differences are insensitive to socialization. However, an evolutionary basis for sex differences in risk preferences does not imply insensitivity. In general, evolved traits are often quite sensitive to environmental cues. An example of such a trait is incest avoidance: we are not sexually attracted to individuals whom we are exposed to at a young age (Shepher, 1983; Fessler & Navarrete, 2004). Indeed, risk preferences have been shown to be sensitive to environmental cues, such as whether one is observed (Daly & Wilson, 2001), and, relatedly, Gneezy et al. (2009) find that the sex gap in competitiveness that exists in Western countries is reversed among the matrilineal Khasi in India.

We also worry that readers might conclude that our results imply that females are inferior to males. However, increased risk-taking is not, by itself, an indicator of increased ability, nor is it necessarily desirable. Indeed, increased risk-taking is often associated with socially undesirable behaviors such as smoking, gambling, and reckless driving.

Novel Predictions

Our findings motivate additional moderators of risk preferences. For example, since sex hormones influence risk preferences, these may vary when hormones vary due to birth control, pregnancy drugs, during the menstrual cycle, or due to environmental stimuli such as flirting (Roney, Lukaszewski, & Simmons, 2007). We also predict that risk preferences vary in the presence of an audience (Daly & Wilson, 2001), in different emotional states (Fessler &

Navarrete, 2004), or in the presence of differing income inequality (Daly & Wilson, 2001), and that these moderators interact with sex.

Our findings also clarify the scope over which we expect sex differences, which largely but imperfectly coincides with the commonly used economic definition of financial risk preferences. For example, the theory predicts a sex difference for ambiguity aversion, since the same theoretical arguments apply in that setting. The theory also predicts sex differences in preferences over skewness rather than variance (E. Dekel & Schochter, 1999). While skewness is equivalent to variance in many naturally occurring distributions like the normal distribution, it is not always so.

Policy Implications

Our results imply that sex differences in risk preferences and hence labor market outcomes would persist even in the absence of discrimination and differential socialization. This has several policy implications. First, divergent risk preferences, unequal professional representation of women, and unequal pay, are not, in and of themselves, evidence for discrimination. Second, differential socialization, such as media portrayals or parental treatment, do not necessarily cause the observed sex differences in preferences, but may well be the consequence.

Third, our review suggests a potentially fruitful approach to addressing the gender gap: institutions to reduce unnecessary rewarding of risk-taking preferences (for a discussion of such practices, see Babcock & Laschever, 2009). For example, if female employees are less likely than males to seek and secure outside employment offers (a risky behavior), organizations that reward outside offers with pay increases may inadvertently contribute to gender disparities in wages. The University of California Senate recently recognized this as a potential cause of disparities in UC faculty wages (Yahr, 2011). While there may be cases in which rewarding risk-taking behavior is necessary or justified, policy-makers should be conscious to avoid rewarding risk-taking when it does not increase efficiency or productivity.

On a separate note, our summary also implies that sex differences are potentially deeply ingrained, and, hence, that encouraging men and women to take equal risk may have negative

consequences, such as decreased performance or increased anxiety for women forced into risky environments. Indeed, there is evidence that women forced into competitive environments demonstrate decreased performance (Gneezy, Niederle, & Rustichini, 2003).

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Footnotes

¹When studies reported correlations, we converted these to OLS coefficients using standard formulas (see, e.g., Quinn & Keough, 2002). When studies reported results using specifications that were incomparable with others', we contacted the authors to request results of a regression of the risk measure on nothing but circulating testosterone and gender. When studies reported results separately for different groups, we pooled them into a single estimate using random effects meta-analysis, and included only the single estimate in our meta-analysis.

²Psychomorph was developed by David I. Perrett and Bernard P. Tiddeman, and its use is common practice (see e.g., Penton-Voak, Jones, Little, Baker, & Tiddeman, 2001; Little et al., 2008).

Table 1

Papers Included in the Circulating Testosterone Meta-Analysis

Paper	Risk Measure	Sample Size	Population	Sex	Race
Apicella et al. (2008)	Gneezy and Potters (1997)	80	Undergraduates	Men	Heterogenous with Controls for Race
Sapienza et al. (2009)	Holt-Laury (2002)	550	MBA's	Both	Heterogenous Population
Schipper (2011)	Holt-Laury (2002)	208	Undergraduates	Both	Heterogenous with Controls for Race
Stanton et al. (2011)	Eckel and Grossman (2002)	298	Not Stated	Both	Not Stated

Note. Papers Included in the Circulating Testosterone Meta-Analysis. Risk measures were categorized based on closest association to well-known measures.

Figures

Table 2

Papers Included in the 2D:4D Meta-Analysis

Paper	Risk Measure	Sample Size	Population	Sex	Race
Apicella et al. (2008)	Gneezy and Potters (1997)	80	Undergraduates	Men	Heterogenous with Controls for Race
Coates and Page (2009)	Sharpe Ratio	53	Traders	Men	Heterogenous Population
Dreber and Hoffman (2009)	Gneezy and Potters (1997)	125	Undergraduates	Both	Caucasians
Sapienza et al. (2009)	Holt-Laury (2002)	550	MBA's	Both	Heterogenous Population
Ronay and Hippel (2010)	Balloon Analogue Risk Task (BART)	59	Undergraduates	Men	Heterogenous Population
Branas-Garza and Rustichini (2011)	Eckel and Grossman (2002) and Holt-Laury (2002)	188	Undergraduates	Both	Caucasians
Garbarino et al. (2011)	Eckel and Grossman (2002)	152	Undergraduates	Both	Caucasians
Schipper (2011)	Holt-Laury (2002)	208	Undergraduates	Both	Heterogenous with Controls for Race
Drichoutis and Nayga (2012)	Holt-Laury (2002)	138	Undergraduates	Both	Caucasians

Note. Risk measures were categorized based on closest association to well-known measures.

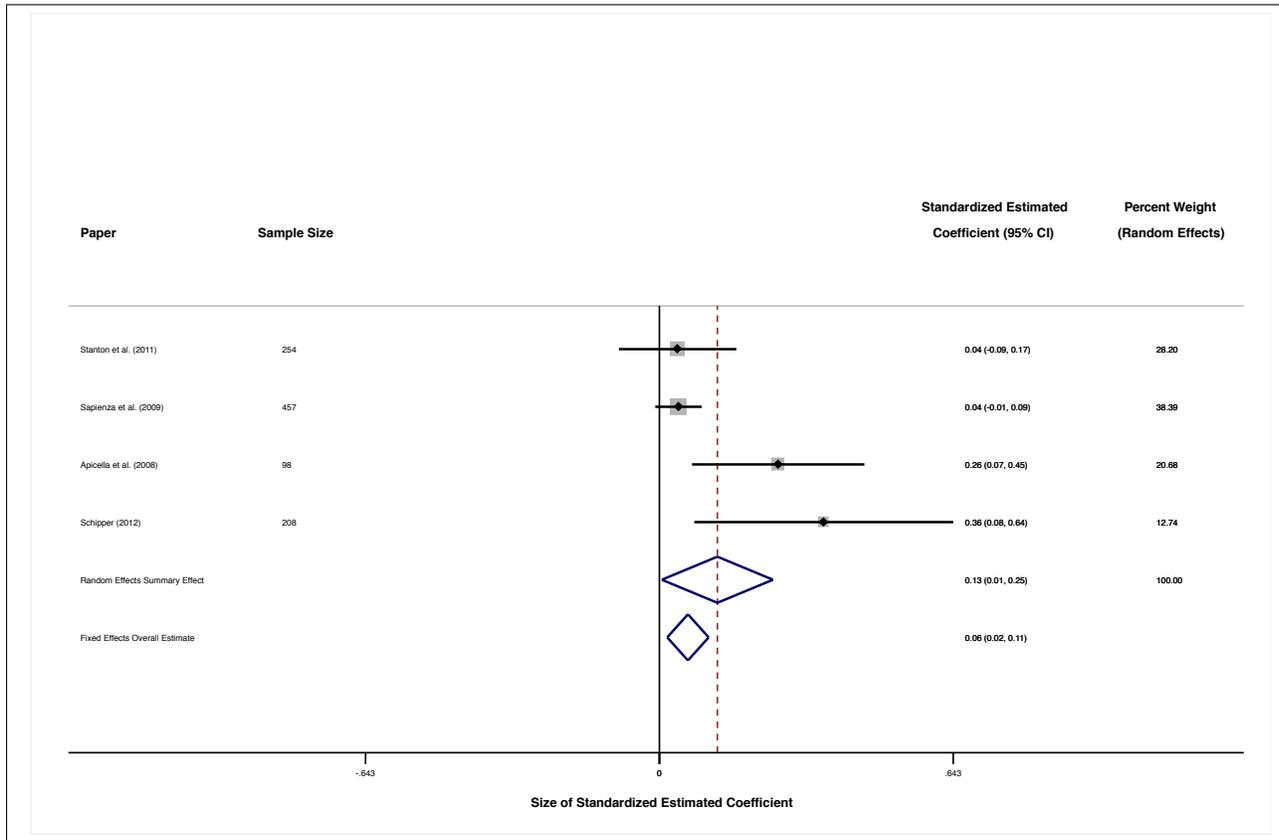


Figure 1. Meta-Analysis of Studies Relating Circulating Testosterone and Risk Preferences. Each row in the figure represents one study, and each black square is the standardized estimate from that study. The magnitude of each standardized estimate is interpreted as the expected number of standard deviations that risk seeking would increase if circulating testosterone increased by one standard deviation. Each black lines represent 95% confidence intervals. The top blue diamond represents the summary effect from a random effects meta-analysis and the bottom blue diamond represents the overall estimate from a fixed effects model. Each diamond is centered at its respective estimated effect, and its width represents the 95% confidence interval.

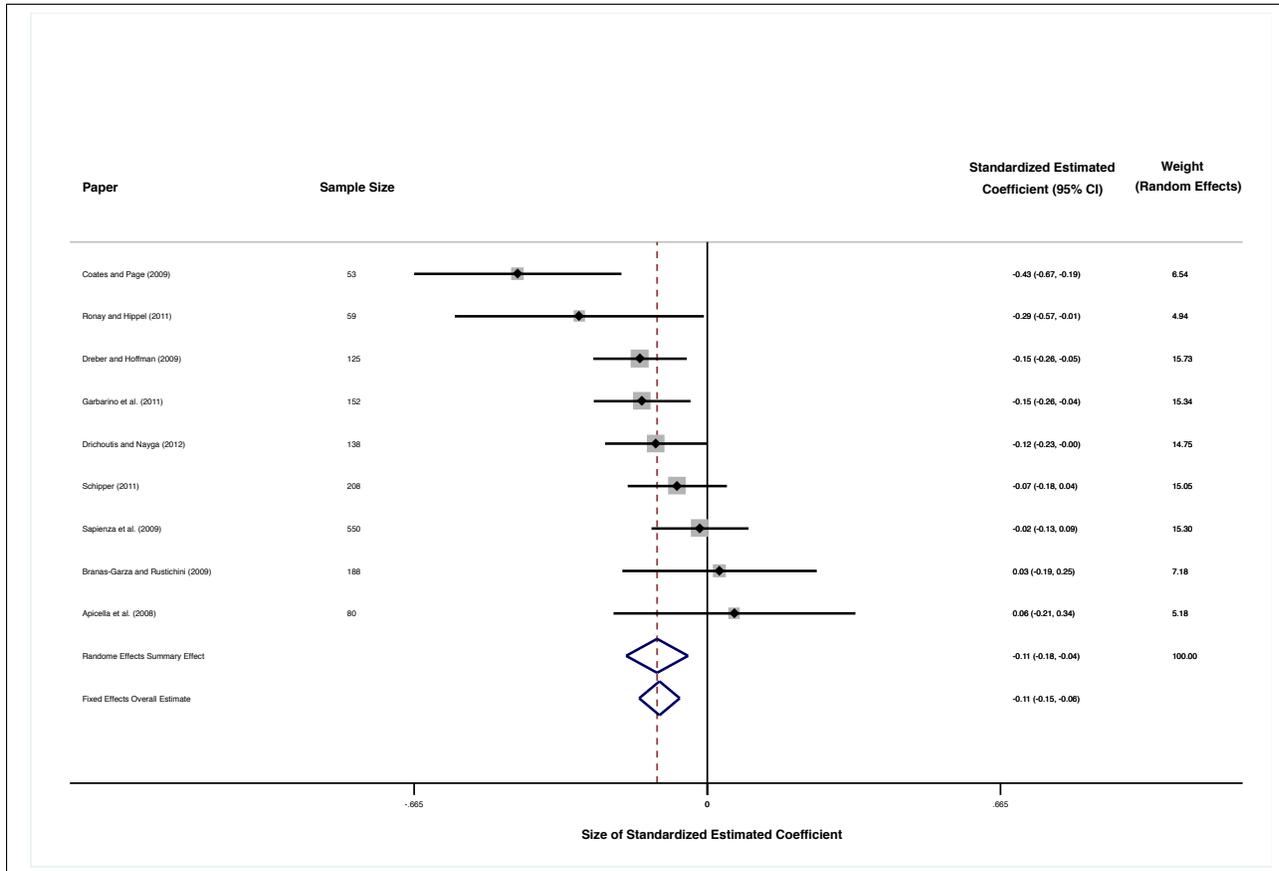


Figure 2. Meta-Analysis of Studies Relating 2D:4D and Risk Preferences. Each row in the figure represents one study, and each black square is the standardized estimate from that study. The magnitude of each standardized estimate is interpreted as the expected number of standard deviations that risk seeking would increase if 2D:4D increased by one standard deviation. The black lines represent 95% confidence intervals. The top blue diamond represents the summary effect from a random effects meta-analysis and the bottom blue diamond represents the overall estimate from a fixed effects model. Each diamond is centered at its respective estimated effect, and its width represents the 95% confidence interval.