DETERMINANTS OF ECONOMIC PREFERENCES

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To my parents, my brother, and my husband

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Acknowledgments

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Finally, I want to thank my husband Johan, with whom I have begun the greatest collaboration of all.

Stockholm, May 2009
Anna Dreber Almenberg

Introduction and Summary of Papers

During my time as a PhD student I have been interested in a large range of subjects, including the biological correlates of risk preferences, the potential role of culture in affecting competitive behaviour among children, the evolution of cooperation, the role of status on the marriage market, and how the timing of price information can affect the experienced pleasantness of a good. As a result, this thesis contains papers on a wide variety of topics. These papers also give a representative picture of what I intend to work more on once I have graduated. The overlying theme is preferences, and more specifically the determinants of preferences, be they biological, cultural, or both. This is an inherently interdisciplinary topic, which is why I've chosen to often collaborate with non-economists.

Some of the papers in this volume have already been published (Papers 1, 2, 3, and 5). Science is a work in progress, and since the publication of these papers new relevant research has been published, in some cases shedding a new light on matters. I look forward to continuing the discussion in future papers.

Paper 1: Testosterone and Financial Risk Preferences (Apicella et al. 2008):

We explore the correlation between prenatal and pubertal testosterone exposure, current testosterone, and financial risk preferences in young men. Using a sample of 98 men, we find that risk-taking in an investment game with potential for real monetary payoffs correlates positively with salivary testosterone levels and facial masculinity, with the latter being a proxy of pubertal hormone exposure. 2D:4D, which has been proposed as a proxy for prenatal hormone exposure, did not correlate significantly with risk preferences.

Paper 2: The 7R Polymorphism in the Dopamine Receptor D4 Gene (*DRD4*) is Associated with Financial Risk Taking in Men (Dreber et al. 2009a):

We examined whether there is an association between financial risk preferences, elicited experimentally in a game with real monetary payoffs, and the presence of the 7-repeat allele (7R+) in the dopamine receptor D4 gene as well as the presence of the A1 allele (A1+) in the dopamine receptor D2 gene in 94 young men. Although we found no association between the A1 allele and risk preferences, we did find that 7R+ men are significantly more risk loving than 7R− men. This polymorphism accounts for roughly 20% of the heritable variation in financial risk taking.

Paper 3: Winners Don't Punish (Dreber et al. 2008):

We experimentally explore the role of costly punishment in a repeated Prisoner's Dilemma. In each round of this game of direct reciprocity people choose between cooperation, defection and costly punishment. Costly punishment means paying a cost for another individual to incur a cost. In control experiments, people can only cooperate or defect. We find that the option of costly punishment increases the amount of cooperation, but not the average payoff of the group. We also find a strong negative correlation between total payoff and use of costly punishment for the individual player. Those people who gain the highest total payoff in our experiment tend not to use costly punishment. However, it could be the case that different results would be observed for other parameter values and longer versions of the experiment, or that punishment is beneficial in asymmetric games or in situations where the risk of retaliation is low.

Paper 4: Outrunning the Gender Gap – Boys and Girls Compete Equally (Dreber et al. 2009b)

In this study we explore competitiveness in children. A related field experiment on Israeli children shows that only boys react to competition by running faster when competing in a race, and that only girls react to the gender of their opponent. Here we test if these results carry over to 8-10 year old Swedish children. We also include two more "female" sports: skipping rope and dancing. Our results contradict previous findings in two ways. First, we fail to replicate the running result. In our study, both boys and girls compete. We also find no gender differences in competition in skipping rope and dancing. Second, we find no clear effect on competitiveness of the opponent's gender, neither on girls or boys, in any of the tasks. Our findings suggest that the gender gap in competitiveness found in previous studies on adults may be caused by factors that emerge later in life.

Paper 5: Lady and the Trump: Status and Wealth in the Marriage Market (Almenberg & Dreber 2009a)

We examine a relatively neglected aspect of intergenerational transmission of economic standing, namely culturally determined status markers and their valuation in the marriage market. We take nobility to be such a status marker. Using data on Swedish marriages, we test the hypothesis that nobility have a greater probability of marrying "up" in terms of wealth. We find a large and statistically significant positive effect for nobility. This finding has implications for the intergenerational transmission of inequality, and for the longevity of the institution of nobility itself.

Paper 6: When Does the Price Affect the Taste? Results from a Wine Experiment (Almenberg & Dreber 2009b)

We designed an experiment that examines how knowledge about the price of a good, and the time at which the information is received, affects how the good is experienced. The good in question was wine, and the price was either high or low. Disclosing the high price before tasting the wine produces considerably higher ratings, although only from women. Disclosing the low price, by contrast, does not result in lower ratings. Our finding indicates that price not only serves to clear markets, it also serves as a marketing tool; it influences expectations that in turn shape a consumer's experience. In addition, our results suggest that men and women respond differently to attribute information.

Paper 1

Testosterone and Financial Risk Preferences

Joint work with Coren L. Apicella, Benjamin Campbell, Peter B. Gray, Moshe Hoffman and Anthony C. Little[1]

ABSTRACT

Many human behaviors, from mating to food acquisition and aggressiveness, entail some degree of risk. Testosterone, a steroid hormone, has been implicated in a wide range of such behaviors in men. However, little is known about the specific relationship between testosterone and risk preferences. In this article, we explore the relationship between prenatal and pubertal testosterone exposure, current testosterone, and financial risk preferences in men. Using a sample of 98 men, we find that risk-taking in an investment game with potential for real monetary payoffs correlates positively with salivary testosterone levels and facial masculinity, with the latter being a proxy of pubertal hormone exposure. 2D:4D, which has been proposed as a proxy for prenatal hormone exposure, did not correlate significantly with risk preferences. Although this is a study of association, the results may shed light on biological determinants of risk preferences.

1. INTRODUCTION

Testosterone, a steroid hormone mainly produced by the testes, not only influences male reproductive physiology and development but also plays an important role in modulating male behavior (Wingfield et al. 1990; Dixson 1998; Nelson 2005). The last 20 years has witnessed a surge in studies that attempt to identify relationships between circulating testosterone concentrations and social behaviors in males of many species (Dabbs 2000; Oliveira 2004; Adkins-Regan 2005). For instance, testosterone has been associated with a number of behaviors in men including increased aggression (Archer 2006), sensation seeking (see, e.g., (Roberti 2004) for a review), hostility (Hartgens & Kuipers 2004), mate-seeking

[1] This paper was published in *Evolution and Human Behavior* (2008, 29(6): 384-390). We thank Johan Almenberg, David Cesarini, Dan Eisenberg, Peter Ellison, Marc Hauser, Magnus Johannesson, Matthew McIntyre, David G. Rand, Paul Schrimpf, Björn Wallace and two anonymous reviewers for helpful comments. We also thank Dave Perrett and Bernard Tiddeman for use of software to measure faces. Anna Dreber is grateful from support from the Jan Wallander and Tom Hedelius Foundation.

(Roney et al. 2003), food acquisition (Worthman & Konner 1987), and dominance (Mazur & Booth 1998). [2] Adaptive explanations for the role of testosterone have been offered for its influence on each of these behaviors, but broadly speaking testosterone modulates those behaviors, which may result in increased reproductive payoffs. These behaviors entail a certain amount of risk, and the consequences can often be costly.

In mammals, testosterone exerts organizational effects on the brain early in ontogeny during sexual differentiation (Phoenix et al. 1959) and again during puberty affecting male behavior in the long term (Sisk et al. 2003). These critical periods of exposure may affect male behavior by programming how individuals respond to the activating or nonpermanent effects of testosterone. Thus, consideration of exposure during these critical periods of development, as well as current circulating levels of testosterone, is essential to fully understand the role testosterone has in influencing behavior.

Two studies have examined the relationship between androgen exposure and financial risk. One study found that financial risk aversion is positively correlated with 2D:4D in a sample of Caucasian men and women in Sweden but not in a heterogenous sample of American men and women in Chicago (Dreber & Hoffman Unpublished work). In another recent study examining a small group of male traders in London, researchers found that, on days when participants' testosterone level was above their median level for all 8 days sampled, they made greater profits than on days when their testosterone was below their median level (Coates & Herbert 2008). The authors attribute this higher profitability as being partly mediated by testosterone's effect on risk, although they did not examine risk-taking directly. Our study is the first study to examine the relationship between testosterone and financial risk preferences in men.

Risk preferences are defined by the trade-off between the variance and the expected value for a given resource. [3] To illustrate this, imagine that you can choose between two options, A and B. Option A entails receiving $50 with certainty, whereas option B entails a 50% chance of winning $100 and a 50% chance of winning $0. The expected outcome is the same for both options: $50. An individual is considered to be risk-neutral when displaying indifference between the two options. A risk-averse individual would prefer the certain option A and be willing to trade off some of the expected gain for a reduced risk. A risk-loving individual

[2] See, e.g., (Wilson et al. 2002) for a discussion of this.

[3] Sensation seeking (Zuckerman 1979) has previously been found to correlate with hormones and a range of behaviors related to risk-taking (Roberti 2004). However, another study finds very low correlation between risk-taking measured from financial gambles, what we call risk preferences, and sensation seeking (Eckel & Grossman 2002).

would prefer option B to option A. Thus, risk can be formalized by looking at the variance in the values of the possible outcomes an option implies.[4] Large individual differences in risk preferences exist, as well as robust gender differences, with men being less risk averse than women (Byrnes et al. 1999; Eckel & Grossman 2002; Croson & Gneezy 2008). One possible mechanism for these differences may be the regulation of testosterone. Currently, little is known about the relationship between testosterone and risk preferences.

In this study, we examine circulating levels of testosterone in men and proxies for testosterone exposure in utero and during puberty. These are 2D:4D (the ratio between the length of the second finger and the fourth ring finger) and facial masculinity. 2D:4D is thought to negatively correlate with prenatal testosterone exposure (Manning et al. 1998; Honekopp et al. 2007), while many masculine facial features are thought to develop during puberty under the action of testosterone (Johnston et al. 2001).

2. METHODS

Ninety-eight males, ages of 18–23 years, mostly Harvard University students, participated in the study. Based on selfreport, 89 subjects were heterosexuals; 7 were homosexuals; and 67% of subjects were white, 10% East Asians, 4% blacks, 4% Hispanics, and 15% "mixed or other." The experiment was approved by the Harvard University's Committee on the Use of Human Subjects in research. One outlier with testosterone levels more than three standard deviations above the mean was excluded from all analyses. 2D:4D was not calculated for 17 individuals due to unclear creases in fingers or incomplete/low-quality images of their hands. Finally, one participant was not photographed.

Testosterone levels were measured from saliva by passive drool. Saliva samples were taken from each participant upon arrival. All samples were collected between 1 p.m. and 3 p.m., and participants were asked to spit through a straw into a small polystyrene tube. All samples were collected between April 9 and June 5, 2007. No significant differences in testosterone concentrations were found between subjects as a function of the hour in which the samples were collected. Saliva samples were frozen on the same day they were supplied and stored at −20°C. At the end of the collection period, all samples were packed in dry ice and shipped via FedEx, overnight delivery, to the Human Behavioral Endocrinology

[4] Risk aversion is the opposite of risk loving, and is determined by the utility function's degree of concavity, implying decreasing marginal returns of utility. Utility, in turn, is a measure of an individual's preference for a good.

Laboratory at the University of Nevada, Las Vegas, NV, USA, where they were assayed. Samples were still frozen upon arrival. Testosterone assays relied on commercially available kits (Salimetrics EIA, product number: 1-2402). Sample and standard reactions were run in duplicate, and the sample concentrations used in the analyses are the averages of the duplicates. Interassay coefficients of variation were 13.2% for low pools and 7.1% for high pools. The intrassay coefficient of variation was 6.8%.

Full frontal facial photographs were taken of all participants without glasses or head wear. Sexual dimorphism measures were taken from points marked on facial features used in previous studies (Penton-Voak et al. 2001; Little et al. 2008). The measures taken here are identical to Little et al. (2008), and more details of the measurements, including a diagram of point placement can be found there. The identification of these features has been found to be reliable in previous studies (Grammer & Thornhill 1994; Scheib et al. 1999). In total, four sexual dimorphism measurements were taken. These were Cheekbone Prominence (ChP), Jaw Height/Lower Face Height (JH/LFH), Lower Face Height/Face Height (LFH/FH), and Face Width/Lower Face Height (FW/LFH). Each of the scores for the four different ratios was converted to a z-score and combined into a single facial masculinity score ([JH/LFH+LFH/FH]−[ChP +FW/LFH]) with high scores indicating a greater degree of masculinity. These measurements have been found to be sexually dimorphic in previous studies (Penton-Voak et al. 2001; Little et al. 2008), although it is still unclear how much of dimorphism is due to variation in pubertal testosterone levels. However, testosterone during human male development facilitates the growth of bone by increasing outside bone diameter and bone mass (Vanderschueren & Bouillon 1995). One study (Verdonck et al. 1999) found that the mandibular ramus length, upper anterior face height and total cranial base length were all significantly shorter in boys with delayed puberty as compared to controls. They also found that boys who were given low doses of testosterone showed a significantly higher growth rate of the mandibular length, ramus length and upper and total anterior face height after 1 year, as compared to untreated controls matched for height.

Participants' hands were scanned with a CanoScan LiDE70 scanner with a resolution of up to 2400×4800 color dpi. The second and fourth digits were later measured from the center of the flexion crease proximal to the palm to the top of the digit, using the Adobe Photoshop tool. The quality of some of the scans was low. When creases were unclear, we erred on the side of caution and did not use the measures thus keeping noise to a minimum. We measured in pixels to two decimals. Additional anthropometry measurements, such as height and weight, were also taken.

We measured participants' risk preferences using an investment game with real monetary payoffs adapted from Gneezy and Potters (Gneezy & Potters 1997). Each participant was given a balance of \$250 and was asked to choose an amount, X, between 0 and 250 that he wished to allocate to a risky investment. The rest, \$250−X, was kept by the participant. A coin flip determined the realization of the risky investment. In case of failure, the money invested was lost, and the participant had \$250−X for a balance. If successful, the money invested was multiplied by 2.5, and the participant had \$250+1.5× for a balance.

At the end of the experiment, one of the subjects was randomly drawn and paid according to the amount on his balance (e.g., according to the choices he made and the outcome of the coin flip). Subjects were told that there would be approximately 100 subjects participating in the study. Because investing is risky but offers higher returns, subjects must weigh a higher expected return against the risk of the investment. This means that a risk-averse individual could choose to invest \$0 into the risky investment, and would thus get \$250 with certainty on his balance. A risk-loving individual, could on the other hand, invest all \$250 into the risky investment. He then would be equally likely to receive \$0 or \$625 and would in expectation get \$312.50. Thus, in this risk measure, subjects do not simply choose between high and low risk; they actively have to trade off expected value against variance. We use X, the fraction invested, as our measure of risk-taking.

Regression analyses are used to examine the association between testosterone, facial masculinity and 2D:4D and risk preferences. Anthropometrics such as height and body weight, as well as age, did not correlate with risk or any of the predictors and were therefore not included as controls in the models. Sexual orientation was, however, a significant predictor of risk and was used as a control in all regressions. All regressions were run with robust standard errors.

3. RESULTS

Table 1 provides descriptive statistics for each measure. Consistent with past findings, there is large individual variation in risk preferences. Self-reported age and ethnicity were not related to the risk measure or the independent variables and were not included in any of the regressions models reported below. However, sexual orientation was found to be a highly significant predictor of risk ($p<0.001$, $R^2=0.078$) and was therefore used as a control in all regression analyses. Sexual orientation remained a significant predictor of risk in all regressions reported, with homosexual men being more risk-averse than heterosexual men. Mann–Whitney two-sided tests reveal that heterosexual and homosexual men do not differ in circulating testosterone (p=0.64), facial masculinity (p=0.34) or 2D:4D (left: p=0.28, right: p=0.40). Our results are based on too small a number of men who described themselves as homosexual, so although we have included them as a control in the regression analyses, we do not to attempt to interpret the results.

Table 1
Summary Statistics for variables used in analyses

Variable	*All Men*	*Heterosexual Men*	*Homosexual Men*
Risk preferences (X)	M=147.47 SD=73.05 N=95	M=153.23 SD=72.28 N=88	M=75 SD=35.36 N=7
Testosterone	M=99.48 SD=33.16 N=95	M=98.70 SD=32.59 N=88	M=109.38 SD=41.26 N=7
Facial masc.	M=–0.023 SD=2.09 N=94	M=–0.079 SD=2.07 N=87	M=0. 68 SD=2.38 N=7
Left 2D:4D	M=.953 SD=0.031 N=85	M=0.952 SD=0.031 N=80	M=0.972 SD=0.043 N=5
Right 2D:4D	M=0.953 SD=0.029 N=88	M=0.953 SD=0.031 N=82	M=0.962 SD=0.018 N=6

No relationship was found between circulating testosterone and facial masculinity (r=0.0716, p=0.448). There have been no studies that have yet to demonstrate a relationship between facialmetric measures of masculinity and circulating testosterone, though one study has found that composite images of men with high testosterone are perceived as more masculine than composite images of men with low testosterone (Penton-Voak & Chen 2004). Moreover, circulating testosterone did not correlate with either left or right 2D:4D (left r=0.1607, p=0.137; right r=0.0711, p=0.506), nor did facial masculinity (left r=0.0136, p=0.901; right r=−0.0624, p=0.562). The fact that neither was correlated with current testosterone suggests that each are valid measures of androgenization during their respective time periods. 2D:4D has not been found to be related to current circulating hormone levels in adults (Honekopp et al. 2007) or to facialmetric measures of masculinity (Burriss et al. 2007).

Fig. 1 shows the positive relationship between risk and testosterone, and Fig. 2 shows the positive relationship between risk and facial masculinity, both when adjusting for sexual orientation. Running ordinary least squares (OLS) regressions and controlling for sexual orientation, a highly significant effect of circulating testosterone on risk preferences is found (β=0.26, R^2=0.15, p=0.004). That is, men with higher testosterone levels are more risk-taking in an investment game. We also find that the group of men that invested all $250 have significantly higher testosterone (M=115.9) than with those that invested less (M=92.6) (Wilcoxon rank sum, controlling for sexual orientation: p=0.0061). Moreover, we find a significant effect of facial masculinity on risk preferences such that men with more masculinized facial features are more likely to make riskier financial decisions (β=0.29, R^2=0.17, p=0.002). When included in the model together, both circulating testosterone (β=0.24, p=0.005) and facial masculinity (β=0.27, p=0.003) remain highly significant predictors of risk and together explain 22% of the variation in risk, when also controlling for sexual orientation.

Figure 1

Risk preferences (dollar amount invested) plotted against testosterone (pg/ml) for all men, adjusted for sexual orientation.

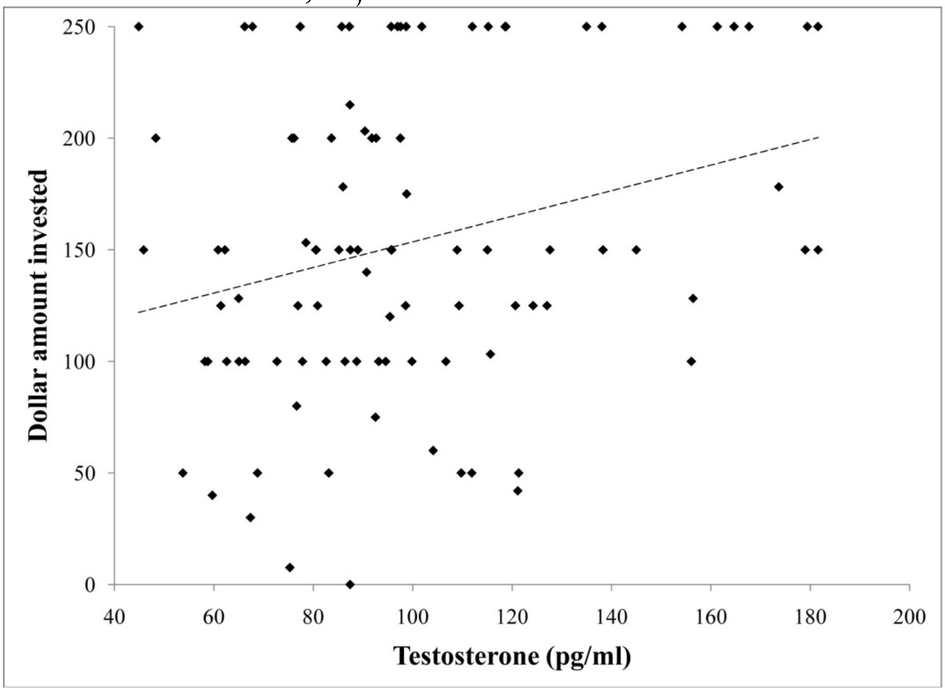
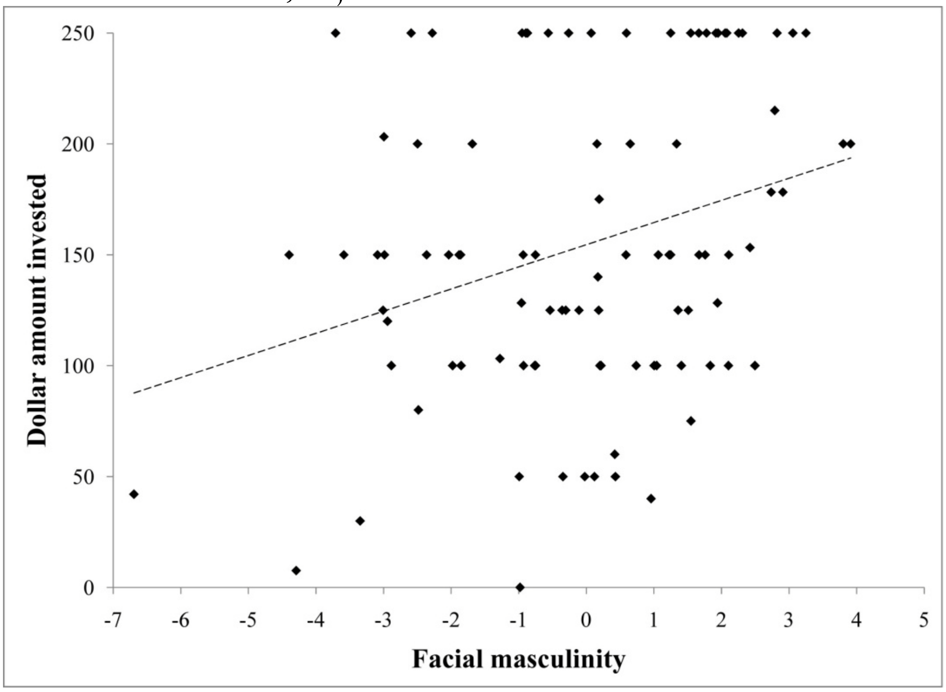


Figure 2
Risk preferences (dollar amount invested) plotted against facial masculinity for all men, adjusted for sexual orientation.



Since the risk measure is a censored variable where participants cannot invest more than $250, we also run a tobit regression. The results are qualitatively similar to those from the OLS reported above. The coefficients on the relevant variables, testosterone (β=0.36, p=0.006) and facial masculinity (β=0.35, p=0.002) are bigger, and the p values, similar.

These effects demonstrate economic significance. When controlling for both salivary testosterone and facial masculinity, a man with a testosterone level one standard deviation above the mean invests $17 more (out of a possible $250) than the average man into the risky investment, while a man with a facial masculinity score one standard deviation higher than the mean invests $9 more than the average man.

Neither left hand nor right hand 2D:4D are significantly correlated with risk preferences (left hand p=0.29, right hand p=0.44), and when controlling for salivary testosterone and/or facial masculinity the p-values increase.

4. DISCUSSION

The findings of this study suggest an association between activational effects of testosterone and, possibly, its organizational effects during puberty and behaviors related to risk-taking in men. Men with higher levels of circulating testosterone and masculine faces are more likely to make risky financial decisions. There was no evidence in this study that 2D:4D is related to risk in men. However, the null result for 2D:4D may be due to the small and ethnically heterogeneous sample.

Monetary transactions are a recent phenomenon in human history, but the acquisition and accumulation of resources by men is not. Money is, in this sense, a proximal currency used to maximize returns in some other currency, such as utility or fitness (Daly & Wilson 2002). Men may have evolved to engage in riskier behaviors compared to women because the potential returns in terms of fitness payoffs can be higher. A woman's reproductive success is limited by the number of offspring she can produce whereas in men it is limited by the number of partners he can attract. Increased resources in men may translate into both increased mating opportunities and increased child survivorship. Indeed, studies have found that women find wealth to be an attractive quality when choosing a mate and value it more than men do in potential mates (Buss 1989; Hitsch et al. 2006). Therefore, there may have been increased selection pressure on men to maximize resource acquisition in order to attract members of the opposite sex.

We suggest that one possible way for a man to increase his resources relative to other men would be to engage in risky financial investments with the possibility of lucrative monetary returns. Since men differ in the degree to which they are willing to trade off expected value against variance, they will also differ in their resulting financial payoffs. Having greater financial payoffs can result in greater access to resources and, thus, greater ability to attract women. Potentially, financial risk-taking might be comparable to other risky male behaviors associated with reproduction. For example, males of many species engage in direct male–male competition over both resources and mates, and this behavior is often activated by testosterone during the breeding season (Harding 1981; Balthazart 1983). In light of financial risk being a potential form of male–male competition, there are clear reasons to expect that men with higher levels of circulating testosterone would be more economically risky as evidenced by our study.

The role of environmental condition in early life and puberty on life history trajectories is becoming increasingly understood. Many traits, both physiological and behavioral, including those defined as male-typical traits, are contingent on environmental input throughout development and adulthood. For instance, dominance status and aggression in some species during adulthood is reduced when condition in early life is poor (Royle et al. 2005). 2D:4D, which is thought to not only correlate negatively with prenatal testosterone exposure but has also been found to correlate negatively with high amniotic testosterone-estradiol ratio (Lutchmaya et al. 2004), has been found to negatively correlate with competitiveness and performance in sports (Manning & Taylor 2001; Honekopp et al. 2006). Additionally, Dreber and Hoffman (2007), using the same risk task used in this study, find that risk aversion is positively correlated with 2D:4D in a sample of Caucasian men and women in Sweden. They also find that the sex difference in risk preferences is diminished when 2D:4D is included as a control in their regression model. However, when examining the same relationship using a more ethnically heterogeneous sample from Chicago of both men and women, they do not find a relationship between 2D:4D and risk. Likewise, the results of this study, which also utilize a diverse sample, did not find a relationship between 2D:4D and risk preferences. Since differences in 2D:4D exist between different ethnic populations (Manning et al. 2004), the relationship may hold only in homogenous samples. In terms of optimizing risk-taking, it is also plausible that decisions may be modified more by acute signals, such as circulating testosterone, based on current environment and condition. Biological influences early in life could play a role, but their effects may be smaller. If the effect is small, it may not have been detected due to the small sample and possible measurement error associated with calculating 2D:4D.

Why facial masculinity should predict economic behavior is less obvious than that of current testosterone. It may be that pubertal levels of testosterone have organizational effects on the brain rendering those with higher levels of exposure more risky. The immuncompetence handicap hypothesis states that masculine traits which develop under exposure to testosterone may signal good genes, since testosterone is thought to suppress the immune system (Folstad & Karter 1992). Indeed, facial masculinity in adolescent boys was found to be correlated with both actual and perceived health (Rhodes et al. 2003) (but see (Boothroyda et al. 2005)), and hand grip strength in male college students was found to be correlated with their ratings of facial masculinity by women (Fink et al. 2007). Therefore, individuals with more masculinized features and higher testosterone may be of higher quality and thus, more likely to take risks because 1) they are used to performing well in a wide range of tasks, and 2) because they are better able to absorb the costs if the outcomes of such risky actions are poor. Thus, androgen exposure may not directly regulate risk preferences but may instead represent markers of health and genetic fitness which in turn shapes risk preferences.

It is also plausible that a reciprocal relationship between phenotypic appearance and environment exists so that masculine men take more risks not only because they are expected to, but also because they are expected to succeed. That is, others may perceive masculine individuals as more likely to succeed when engaging in risky behaviors. Such perceptions by conspecifics may not only skew individuals' self-perceived level of risk but may also affect the actual outcomes of certain risky behaviors. Thus, pubertal testosterone exposure could shape lifelong risk perceptions directly through androgenization of the brain or indirectly through masculinization of the face which, in turn, affects how individuals act and react in their environment.

This is the first study to specifically examine an association between testosterone exposure and financial risk preferences, though a few studies have attempted to examine the hormonal underpinnings of other economic behavior. For example, one study finds that women in the menstrual phase of their cycle, when estrogen and progesterone are low, are more risktaking during bid in a first price auction (the person with the highest bids "wins" the auction), whereas during other phases of the menstrual cycle, they are more risk averse (Chen et al. 2005). In a study on day traders, Coates and Herbert (2008) find higher testosterone levels on days when traders made above average profits. Another study examined the role of testosterone in men's performance in the ultimatum game (Burnham 2007), a negotiation game where a proposer makes an offer of how to allocate money between himself and a responder. The responder, in turn, either accepts or rejects the offer, with the resulting outcome of zero payoffs for both parties if the responder rejects. While high- and low-testosterone men gave similar offers, high-testosterone men were more likely to reject selfish offers. The fact that high-testosterone men were more likely to reject unfair offers and receive no economic benefits suggest that they perceive low offers as challenges and may be more concerned with maintaining their reputations and increasing the likelihood that future interactions, if they occur, will be more economically favorable (Burnham 2007). Another interesting study uses a classical twin design to demonstrate that risk preferences elicited experimentally are heritable (Cesarini et al. In Press). Since circulating testosterone levels are under moderate to strong genetic influences (Harris et al. 1998; Ring et al. 2005), our findings suggest a possible hormonal pathway through which genetic transmission of risk may operate, though such a conclusion necessitates continued research.

There are a number of limitations with this study. First, this is a test of association where subjects were tested on only 1 day. We therefore cannot make any claims about causality nor can we discuss the salivary testosterone measures as reflecting stable, trait-level values or current state-level values. Further work should examine whether natural intraindividual variation in testosterone predicts financial risk as well as examine the effects of exogenously administered testosterone to determine causality. Moreover, this study mainly consisted of Harvard students, and we did not control for variation in socioeconomic status. We suggest future work include more diverse sets of participants where the effects of socioeconomic status can be examined.

Given the scant literature in the field of biological economics, this study may afford some important insights into the biology of economic risk preferences. This is the first study to examine the relationship between both activational and organizational effects of testosterone and economic behavior. Men with testosterone levels that were one standard deviation above the mean invested almost 12% more of their portfolio in a risky financial game compared to men with average testosterone levels. Likewise, men with sexually dimorphic facial features invested more in financial risks. Having masculinized facial features one standard deviation above the mean translated into more than 6% higher monetary investments than men with average masculinity features. Insofar as laboratory findings generalize to higher stakes, these biological influences could potentially have a significant impact on the economic welfare of given individuals. Given the important welfare consequences associated with financial investments, understanding the biological mechanisms that mediate such choices is of utmost importance.

Paper 2

The 7R Polymorphism in the Dopamine Receptor D4 Gene (*DRD4*) is Associated with Financial Risk Taking in Men

Joint work with Coren L. Apicella, Dan T.A. Eisenberg, Justin R. Garcia, Richard S. Zamore, J. Koji Lum and Benjamin Campbell[5]

ABSTRACT

Individuals exhibit substantial heterogeneity in financial risk aversion. Recent work on twins demonstrated that some variation is influenced by individual heritable differences. Despite this, there has been no study investigating possible genetic loci associated with financial risk taking in healthy individuals. Here, we examined whether there is an association between financial risk preferences, elicited experimentally in a game with real monetary payoffs, and the presence of the 7-repeat allele (7R+) in the dopamine receptor D4 gene as well as the presence of the A1 allele (A1+) in the dopamine receptor D2 gene in 94 young men. Although we found no association between the A1 allele and risk preferences, we did find that 7R+ men are significantly more risk loving than 7R− men. This polymorphism accounts for roughly 20% of the heritable variation in financial risk taking. We suggest that selection for the 7R allele may be for a behavioral phenotype associated with risk taking. This is consistent with previous evolutionary explanations suggesting that selection for this allele was for behaviors associated with migration and male competition, both of which entail an element of risk.

1. INTRODUCTION

Risk preferences are central to any model of human decision making, and a number of studies have documented substantial heterogeneity in individuals'

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willingness to take financial risks—that is, their willingness to trade off increasing variance of returns against greater expected returns (Barsky et al. 1997). Some individual variation in preferences can be explained by such demographic variables as sex (Barsky et al. 1997; Byrnes et al. 1999), age (Barsky et al. 1997; Donkers et al. 2001), race (Barsky et al. 1997; Fan & Xiao 2005), religion (Barsky et al. 1997), education (Grable 2000; Donkers et al. 2001; Grable & Joo 2004), and socioeconomic status (Grable 2000; Grable & Joo 2004). However, these variables explain only a modest share of the variation. Recent work based on samples of twins showed that risk preferences are heritable (Cesarini et al. Unpublished manuscript). Approximately 25% of the individual variation in risk taking, as measured by actual pension investment decisions and elicited experimentally using a gambling task, was explained by heritable differences (Cesarini et al. In Press). The challenge for behavioral scientists is to now identify the genetic loci associated with such risk preferences.

Risk preferences may be influenced by dopaminergic pathways in the brain. These pathways play a role in regulating the anticipation of rewards (Wise 2002; Kelley et al. 2005) as well as the motivation for obtaining rewards (Kelley 2004) and include the ventral tegmental area, nucleus accumbens, and the prefrontal cortex. Activation of these pathways can result in increased physiological arousal and intense feelings of well-being or pleasure (Heath 1964; Peterson 2005), which in turn may increase an individual's propensity to take risks. Dysfunction in these pathways can affect reward processing, motivation, and, consequently, decision making. Individuals who weigh anticipated rewards heavily may be more likely to take risks since rewards induce approach-related behaviors. Two genes known to be involved in the regulation of the dopaminergic system are the dopamine receptor D4 (*DRD4*) gene and the dopamine receptor D2 (*DRD2*) gene.

The *DRD4* gene has been investigated as a candidate gene for modulating a number of approach-related behaviors (Munafo et al. 2008), but not financial risk taking per se. Particular interest has been paid to the 48-bp variable number of tandem repeats (VNTR) polymorphism in exon III of the *DRD4* gene, which consists of 2–11 repeats (Ding et al. 2002) likely involved in modulating expression (Schoots & Van Tol 2003). Specifically, the 7-repeat (7R+) allele is associated with decreased ligand binding (Asghari et al. 1994) and has been shown to require higher levels of dopamine to produce a response of similar magnitude as compared with smaller-sized variants (Asghari et al. 1995), although its functional significance has not been definitively characterized. This blunted response to dopamine may cause inhibitory neurons that use the 7R receptor to require increased dopamine for "normal" functioning (Swanson et al. 2000) and may thus contribute to individual differences in personality and behavioral traits that are associated with dopamine levels.

Allelic variation in the *DRD4* dopamine gene has been associated with novelty seeking (for a review, see (Munafo et al. 2008)). The presence of the 7R allele itself has been associated with alcoholism (Laucht et al. 2007), behavioral disinhibition (Congdon et al. 2008), attention deficit/hyperactivity disorder (Li et al. 2006), pathological gambling (Perez de Castro et al. 1997), and impulsivity (Eisenberg et al. 2007b). While the personality trait most widely studied in relation to *DRD4* is novelty seeking, many studies have failed to find significance (Munafo et al. 2008). The most recent meta-analysis conducted also failed to support a relationship between *DRD4* (VNTR) and novelty seeking as well as impulsivity (Munafo et al. 2008). However, given the small effect sizes reported for *DRD4* (VNTR) on personality, small differences between studies can lead to nonsignificant findings. Indeed, there was evidence of between-study heterogeneity in this meta-analysis. The role of *DRD4* (VNTR) polymorphism in personality, and specifically on approach-related behaviors, is thus inconclusive.

Another receptor for the neurotransmitter dopamine is the *DRD2* gene, coded for by locus 11q23. A single-nucleotide polymorphism with two variants exists at the TaqI A locus, located downstream of *DRD2* (Dubertret et al. 2004). Although its functional significance is unclear, the less frequent A1 allele has been associated with decreased D2 receptor expression in the striatum (Noble et al. 1991; Thompson et al. 1997), as compared with the A2 allele (but see (Laruelle et al. 1998)). Carriers of the A1 allele, in contrast to carriers of the A2 allele, have diminished glucose metabolism in the brain (Noble et al. 1997) and exhibit reduced dopaminergic activity (Berman & Noble 1995). The A1 allele has been associated with substance abuse (Noble 2003) (Noble, 2003) impulsivity (Eisenberg et al. 2007a), pathological gambling, novelty seeking, and sensation seeking (Ratsma et al. 2001). A recent study examined the A1 allele in relation to personality scores measuring reward-related traits and found that women with the A1 allele were more responsive to rewards (Lee et al. 2007). We predict that individuals with the A1 allele will be more risk loving as they may be more responsive to rewards.

Using a behavioral measure of risk involving real financial incentives, we examined the relationship between risk preferences and allelic variation in *DRD4*, focusing on the presence of the 7R allele, as well as allelic variation in *DRD2* in 98 young men. An advantage of eliciting preferences experimentally, with financial incentives attached to performance, is that we can infer preferences from choices made by our subjects rather than rely on selfreported hypothetical decisions (Hertwig & Ortman 2001).

2. METHODS

2.1. Participants

Participants were recruited by flyers distributed at the Harvard University campus and via e-mail solicitation to undergraduate residential houses. A total of 98 male subjects between 18 and 23 years old participated in the study. Subjects were excluded if they reported current use of psychotropic medications or having a diagnosis of bipolar depression, pathological gambling, and/or attention deficit hyperactivity disorder. The ethnic composition of the sample was determined by self-report: 66 individuals reported themselves as European, 9 as Asian, 4 as Hispanic, 4 as African American, and 14 as being of other or several categories. A total of 89 individuals reported themselves as heterosexual, and 7 did as homosexual. One individual was a self-reported bisexual, and another reported having an unknown sexual orientation. Neither of these two individuals was included in the analyses when controlling for sexual orientation. All aspects of the study were approved by Harvard University's institutional review board. Written consent was obtained from all subjects before they participated in the study.

2.2. Data Collection

For data collection, subjects came to a central location. After receiving an explanation of the study procedures, each subject provided an unstimulated saliva sample by spitting through a straw into a vial. A second oral sample using 10 ml of Scope mouthwash was also obtained, and it was through this sample that we collected DNA. Participants then filled out a questionnaire including the risk measure adapted from Gneezy and Potters (1997) and background information. After completion of the questionnaire, anthropometric measures and a frontal facial photograph were obtained, as well as a final saliva sample. For more information on the hormonal analysis, see the work of Apicella et al. (2008).

2.3. Risk Preferences

We measured participants' risk preferences using an investment game with real monetary payoffs (adapted from Gneezy & Potters, 1997). Subjects were "given" a balance of $250 and asked to choose an amount, $X, between $0 and $250, to invest into a risky investment. The rest ($250−$X) was kept by the subjects. A coin flip determined the outcome of the risky investment; thus, the probability of success was 0.5. In case of failure, the money invested is lost, and the subject has \$250−\$X on his balance. If successful, the money invested is multiplied by 2.5, and the subject has \$250+1.5X on his balance. This means that a very risk-averse individual could choose to invest \$0 into the risky investment and would thus get \$250 with certainty. A risk-loving individual could, on the other hand, invest all \$250 into the risky investment; he then would be equally likely to receive \$0 as \$625 and would in expectation get \$312.5. At the end of the experiment, one of the subjects was randomly drawn and paid according to the amount on his balance (e.g., according to the choices he made and the outcome of the coin flip). Subjects were told that there would be approximately 100 subjects participating in the study. Because investing is risky but offers higher returns, subjects must weigh a higher expected return against the risk of the investment. We thus used \$X, the fraction invested, as our measure of risk taking.

Since only one participant is selected for actual payment, a legitimate concern is that this introduces noise in the elicitation of preferences. The most comprehensive review to date on the effects of financial incentives on performance reviewed 74 experiments with no, low, or high performance-based financial incentives (Camerer & Hogarth 1999). Their modal result was that incentives had no effect on mean performance, but they did note that incentives shift performance toward the equilibrium prediction in cognitively complex tasks. Independently, another study reached a similar conclusion (Smith & Walker 1993). They suggested a model in which the laboratory subject faces a tradeoff between decision costs and the benefits of taking the action that maximizes his expected utility, conditional on his preferences. Compared with more complex laboratory experiments, the risk elicitation measure we used is cognitively simple and ought to pose no problem of comprehension in a sample of predominantly Harvard undergraduates. Thus, introducing a small probability of winning money is likely enough to ensure that risk preferences are measured with reasonable precision.

It is also important to note that the small stake criticism against laboratory experiments most forcefully applies to experiments designed to measure social preferences (e.g., giving in dictator games). The concern is that utility maximization is influenced not only by wealth maximization but also by an individual's desire to “do the right thing” or make the “moral” choice (Levitt & List 2007) but that such concerns will be suppressed as the opportunity cost of making the moral choice rises when stakes are sufficiently high. It is not obvious why risk preferences elicited experimentally with low stakes should be biased in a particular direction. Recent evidence also suggests that laboratory measures of risk aversion, using small stakes, predict risk taking in the field (Dohmen et al. 2005). Ultimately, noise would merely lead to attenuation bias in the estimated correlation between risk and the selected polymorphisms.

Finally, the validity of the commonly used experimental procedure where subjects play multiple rounds during an experiment and with one round being randomly selected for payment was recently tested (Laury 2006). That work did not report differences between paying for 1 out of 10 rounds or for all 10 rounds when payments are low. This provides support for the hypothesis that behavior is not entirely contingent upon the probability that the outcome will be realized, at least in the simple experiment designed to measure risk aversion that Laury considered.

2.4. Genotyping

Buccal cell samples for DNA analysis (Feigelson et al. 2001) were obtained from 98% (96/98) of the recruited male subjects. All collected samples were shipped to the Binghamton University Laboratory of Evolutionary Anthropology and Health. DNA was extracted using an abbreviated version of the silica extraction protocol (Boom et al. 1990) (described by (Lum et al. 1998)). All genotyping procedures were approved by Binghamton University's human subjects research review committee. Genotyping was performed for the two candidate genes only.

2.4.1.DRD4 48-bp VNTR

The human *DRD4* gene on chromosome 11 contains a 48-bp VNTR polymorphism in exon III. It varies between 2 and 11 repeats of a similar 48-bp coding region sequence, with a trimodal distribution of 2-, 4-, and 7-repeat alleles (2R, 4R, and 7R) in most populations (Ding et al. 2002).

Sufficient DNA for *DRD4* PCR amplification was extracted from 99% (95/96) of the buccal cell samples. Previous studies highlighted problems associated with consistent genotyping of the *DRD4* VNTR region (Hamarman et al. 2004; Eisenberg et al. 2007b; Eisenberg et al. 2008), suggesting multiple PCR runs for each sample to control for allelic dropout. Thus, the PCR was modified to reflect the high GC content (see below) and all samples that were initially scored as homozygotes were reanalyzed two additional times with different starting template concentrations to confirm genotypes. The PCR consisted of 1× QSolution (Qiagen), 1× buffer (Qiagen), 1 µM primer 1 (5'GCGACTACGTGGTCTACTCG 3'), 1 µM primer 2 (5'AGGACCCTCATGGCCTTG 3'), 200 µM deoxy-ATP, 200 µM deoxy-TTP, 200 µM deoxy-CTP, 100 µM deoxy-ITP, 100 µMdeoxy-GTP, 0.3 U of HotStar Taq (Qiagen), and 1 µl of DNA template, in a total volume of 10 µl.

The PCR profile began with 15 min at 95°C for enzyme activation and denaturing of template DNA followed by 40 cycles consisting of 1-min denaturation at 94°C, 1-min annealing at 55°C, and 1.5-min extension at 72°C; it finished with a 10-min extension at 72°C. Amplicons were electrophoresed through 1.4%–2.0% agarose gels containing ethidium bromide, and genotypes were determined by comparison with a 100-bp ladder. Subjects were then scored as either 7R+ (at least one allele of at least 7 repeats) or 7R− (both alleles less than 7 repeats).

2.4.2. DRD2 TaqI A

The human *DRD2* gene located on chromosome 11 contains an often studied single-nucleotide polymorphism called TaqI A. PCR amplification was successful for 97% (93/96) of the buccal cell samples. The PCR for *DRD2* consisted of 0.5 μM forward (5' CAC GGC TGG CCA AGT TGT CTA 3') and 0.5 μM reverse (5' CACCTTCCTGAGTGTCATCAA3') primers, 200 μM deoxy-NTP, 2.5 mM MgCl2, 0.25 U of HotStar Taq (Qiagen), 1× buffer (Qiagen), and 2.5-μl DNA template, in a total volume of 10 μl. The PCR profile began with 15 min at 95°C for enzyme activation and denaturing of template DNA followed by 40 cycles consisting of a 30-s denaturation at 94°, 30-s annealing at 55°C, and 1-min extension at 72°C; it finished with a 7-min extension at 72°C. The PCR product was digested with the TaqI enzyme overnight at 65°C as per the manufacturer's specifications (New England Biolabs). Amplicons were electrophoresed through 1.4%–2.0% agarose gels containing ethidium bromide, and genotypes were determined by comparison with a 100-bp ladder. The A1 alleles do not contain a TaqI restriction site, and so the 300-bp PCR product is not cut. In contrast, the TaqI restriction site containing A2 alleles yields 125- and 175-bp fragments after digestion. Subjects were thus scored as either A1− or A1+ based on the presence of at least one TaqI restriction site (i.e., A1/A1=A1−; A1/A2 or A2/A2=A1+).

Hardy–Weinberg (HW) equilibria were tested with the HWE program written by John Brzustowski. HW equilibrium was tested with Fisher's exact test, and *DRD4* was tested with the Markov chain algorithm (Guo & Thompson 1992). Both *DRD2* and *DRD4* genotype frequencies were in accordance with HWequilibrium (*DRD2*: p=.1584, Fisher's exact test; *DRD4*: p=.717, Markov chain algorithm).

2.5. Statistical analysis

We used linear regressions (ordinary least squares) throughout. Subjects were classified according to the presence (7R+) or absence (7R−) of the7Rof *DRD4* and according to the presence of the A1 allele (A1+) of *DRD2*. We found no significant difference in the presence of 7R or A1 when comparing individuals in different ethnic groups or heterosexual men with homosexual men. We also found no significant difference in risk preferences between ethnic groups.

3. RESULTS

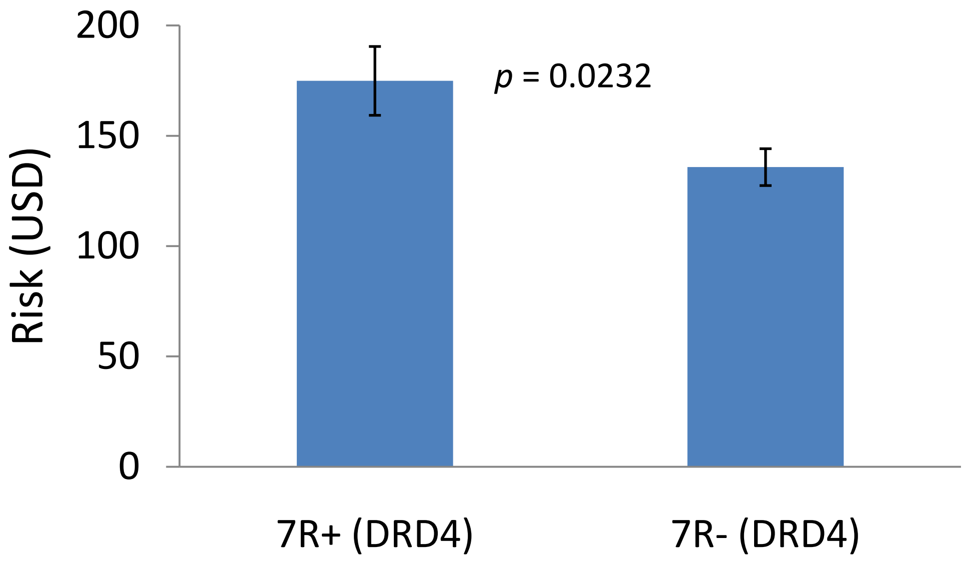
Our subject pool was composed of 24 individuals with at least one 7R allele (7R+) and 70 individuals without the 7R allele (7R−) for *DRD4*. See Table 1 for summary statistics. A first test of the hypothesis comes from a mean comparison of these two groups. Regressing risk taking on a dummy variable taking a value of 1 if the individual is 7R+ and that of 0 otherwise, we found a statistically significant difference (coefficient=39.09, p=.023). On average, 7R+ individuals invest $39 more than individuals who are 7R−. This difference is illustrated graphically in Fig. 1. The R2 from this regression is 0.05, suggesting that 5% of the variation in risk taking, or approximately a fifth of the heritable variation, is accounted for by the 7R+ polymorphism. In order to make our analysis more stringent, we also performed a Bonferroni correction. This is common when multiple hypotheses, such as multiple candidate genes, are tested. Since our p value is 0.023, our result remains significant also when corrected.

Table 1
Summary statistics

	Mean	SD	N
Risk (USD invested)	145.71	72.79	98
7R+	0.255	0.438	94
A1+	0.391	0.491	92
1 if Caucasian	0.680	0.469	97
1 if Asian-American	0.093	0.292	97
1 if Hispanic/Latino	0.041	0.200	97
1 if African-American	0.041	0.200	97
1 if other ethnicity	0.144	0.353	97
1 if Homosexual*	0.073	0.261	96
Testosterone (pg/ml)	100.40	33.59	97
Facial masculinity	-0.060	2.11	96

*Ethnicity and sexual orientation data were self-reported. Facial masculinity was constructed from four standardized measures of sexual dimorphism.

Figure 1
Men with *DRD4* 7R+ invest more money in a financial risk game.
Error bars indicate standard errors.



We have previously reported an association between risk taking and circulating testosterone, sexual orientation, and facial masculinity (Apicella et al. 2008). Moreover, there are differences in the frequency of 7R+ between populations (Chen et al. 1999), although we did not find any difference in our sample (see Section 2.5). Controlling for these variables (e.g., circulating testosterone, facial masculinity, sexuality, and ethnicity) does not appreciably change our estimated coefficient (coefficient=36.59, p=.026).

Regression analysis revealed no significant association between the A1 allele of the TaqI A *DRD2* and risk taking. When comparing men with the A1 allele (A1+, n=36) with those without the A1 allele (A1−, n=56), the difference is nonsignificant (p=.813). The p values do not reach conventional levels of significance when other covariates are included.

4. DISCUSSION

We found a significant correlation between the presence of the 7R allele of the *DRD4* gene and risk taking in a laboratory task. The difference in investment between individuals who are 7R+ and individuals who are 7R− is approximately half a standard deviation ($39 of $250). Our results are consistent with the hypothesis that individual variation in risk preferences may be mediated partly by allelic variants coding for differences in *DRD4* receptor gene expression in key brain areas associated with reward processing. However, we did not find carriers of the A1 allele for *DRD2* at the TaqI A locus to be more risk tolerant. These findings are consistent with the hypothesized link between reward pathways of the brain and risk taking. This is the first study to establish a correlation between a specific gene and financial risk taking in a normal (i.e., nonpathological) sample, and recent unpublished findings corroborate this link (Kuhnen & Chiao, unpublished data).

The results from this study suggest that one underlying mechanism responsible for heterogeneity in financial risk preferences is the dopamine system—more specifically, allelic variation in the *DRD4* dopamine receptor gene. The D4 receptor, expressed by this gene, in part mediates the physiological actions of dopamine, and the 7R allele is known to have a blunted response to dopamine (Asghari et al. 1995). Dopamine itself is closely related to rewardseeking behaviors (Arias-Carrion & Poppel 2007), although the mechanisms by which it affects reward-related decision making are still unclear.

Indeed, neuroimaging studies exploring the neural correlates of financial risk taking have implicated dopaminergic pathways. For instance, ventral striatum activation, including the nucleus accumbens, correlates with the magnitude of anticipated monetary reward and predicts risky investment decisions (Knutson et al. 2001; Knutson et al. 2005; Kuhnen & Knutson 2005; Knutson & Bossaerts 2007). Some studies also demonstrated increased ventral striatal activity as the probability of obtaining monetary rewards increases (Abler et al. 2006; Yacubian et al. 2006), but one study did not (Knutson & Cooper 2005). Similarly, medial prefrontal activity is correlated with increased probability of monetary reward (Knutson & Cooper 2005; Yacubian et al. 2006).

It has been proposed that there exist two separate neural systems that value monetary reward (McClure et al. 2004). One such system values immediate monetary reward and is marked by increased activation in the ventral striatum and areas of the medial prefrontal cortex relative to the lateral prefrontal and parietal cortices (McClure et al. 2004). The converse was found for the second system, which values delayed rewards. In this system, greater activation is seen in the lateral prefrontal and parietal cortices relative to the ventral striatum and medial prefrontal cortex (McClure et al. 2004). This finding may help explain why we did not find an association between the TaqI A polymorphism of the *DRD2* gene and risk taking in our study. The *DRD2* gene codes for D2 receptors that play a relatively more prominent role in the striatum, while the *DRD4* gene codes for D4 receptors that play a relatively more prominent role in cortical regions not limited to the prefrontal cortex (see (Eisenberg et al. 2007a)). Participants in our task were aware that winnings would only be received at the completion of the entire study and, in this sense, expected that rewards were delayed. Thus, the null result found for TaqI A of *DRD2* may be due to the delayed nature of the risk task itself. Therefore, future work should examine the possible role of *DRD2* on financial risk taking where outcomes are immediately supplied. Finally, it is worth noting that TaqI A is a nonfunctional polymorphism with a history of inconsistent results when related to phenotypic variation. This may be the case because it is susceptible to confounding due to varying linkage patterns by lineage and/or population stratification (Hutchison et al. 2004). That is, both phenotypic values and allele frequencies might vary between populations, while the polymorphism itself does not cause the phenotypic variation. This is particularly nefarious when the underlying population structure is unknown.

Although our results suggest that reward system function may be influenced by the D4 dopamine receptor gene, we have no measure of dopamine activity in the brain, and, consequently, the mechanism we propose is speculative. The findings reported here are only suggestive of an association and necessitate future work integrating both molecular- and cellular-level data with behavior. Specifically, research should examine neural activity in conjunction with allelic variation in *DRD4* to better understand the mechanism(s) by which polymorphisms in this gene influence financial risk taking. We emphasize the exploratory nature of the results reported here and the need for replication studies involving larger and more diverse populations, where both sexes are examined.

As noted by (Cesarini et al. In Press) and (Camerer 2003), a few stable correlates to experimentally elicited preferences have been found. The results reported here suggest that one reason is that some of the studied variation is genetic in origin and that the underlying genetic variation maps to observable variables imperfectly. Beyond shedding light on an important source of variation, the results serve as a useful reminder that the parent–offspring correlation (Charles & Hurst 2003) in risk preferences is likely the result of a collection of heterogeneous mechanisms, including genetic inheritance. We know of only one study that linked a gene with behavior in an experimental game, by reporting an association between the amount of money donated in a dictator game and variants of the AVPR1 gene (Knafo et al. 2008).

We suggest that selection for the 7R allele may have arisen partly due to its effects on increased risk taking. This claim is compatible with a number of evolutionary explanations previously offered. It has been estimated that the 7R allele is substantially younger than the ancestral 4R allele, and its frequency increased over the past 40,000–50,000 years under positive selection (Ding et al.

2002; Wang et al. 2004); it now likely exists as a balanced polymorphism (Ding et al. 2002). The reported associations between 7R allele and personality traits, such as novelty seeking and impulsivity, as well as world distributions of 7R+ frequency, where it is rare in East Asians and Kung Bushmen, moderate in Europeans and Africans, and common in South American Indians (Chen et al. 1999), have provided the basis for the main evolutionary hypotheses that explain selection on *DRD4*.

The first evolutionary explanation is that selection mighthave been for migratory behavior (Chen et al. 1999), which may have led to the exodus out of Africa. Indeed, the long allele is more common among nomads than in settled populations (Chen et al. 1999), and it is associated with better health in nomads, but not sedentary individuals of the same population (Eisenberg et al. 2008). A similar explanation is that selection may have been for a "response-ready" phenotype during critical periods, such as times of food scarcity (Ding et al. 2002). This response-ready adaptation might have also played a role in the migration out of Africa, but subsequent selection would have been environment dependent (Wang et al. 2004). The migration morph does not explain why the 7R allele may have persisted at low frequencies long before the migration out of Africa (Harpending & Cochran 2002), and although a response-ready phenotype could be advantageous in many environments, the characterization of such a phenotype remains ambiguous.

The other major evolutionary explanation for human variation in *DRD4* is one involving sexual selection. In male competitive societies, men who carried the 7R allele may have enjoyed a greater reproductive advantage in both resource competition and direct competitions with other men over mates (Harpending & Cochran 2002). This advantage would have increased after the advent of agriculture (Harpending & Cochran 2002). In preagricultural societies, much male reproductive effort likely went to parenting effort rather than mating effort compared with lowdensity agricultural societies, where males have more free time to compete with other males (Harpending & Cochran 2002). Since competitions are risky, bearers of the 7R allele may have had an advantage if they were impulsive and unpredictable (Harpending & Cochran 2002). Since women also have the 7R allele, it may be that the effect of the 7R allele in men on aggression, competition, and risk taking is testosterone dependent, although we found no significant interaction between testosterone and 7R+ on risk preferences among men ($p=.983$) when controlling for testosterone and 7R+. Future work with women should examine the role of the 7R allele on risk, competition, and aggression.

Our assertion that selection for the 7R allele may have been for a risky behavioral phenotype is complementary to all the aforementioned explanations. Taking financial risks is a recent phenomenon in human history, although risk taking itself is not. Decision making is central to both survival and fitness, and all decisions, including whether to migrate out of Africa and explore new ecological niches, engage in direct male–male competition, or invest money in a particular stock, entail some degree of risk. As previously mentioned, low levels of the 7R allele may have persisted in low frequency for much of human history, and, indeed, risk taking is a strategy that is advantageous under many conditions although the potential payoffs can be greater in some environments (e.g., in those environments where resources are scarce and when the possible rewards, such as increased access to mates, are high). Our suggestion is also in line with the finding that the allele is likely frequency dependent (Wilson 1994; Ding et al. 2002; Harpending & Cochran 2002; Eisenberg et al. 2008) since the payoffs of many risky behaviors, especially those involving direct competition, depend on (1) how others respond to the behavior and (2) the frequency of risk takers in the population.

Regardless of the evolutionary dynamics that led to the emergence of the 7R allele and its maintenance, the fact is that this polymorphism is a quantitatively important source of individual variation in our risk-taking task. The effect of this polymorphism on risk taking is very high compared with those found for other complex phenotypes. The 7R allele explains 5% of the variation in risk preferences, or about a fifth of the estimated heritability of financial risk taking previously reported (Cesarini et al. In Press), although the laboratory measure of risk used for this heritability estimate is different from the measure used here. The remaining 80% of the heritability still remains unexplained. Future work should examine other variants of the *DRD4* gene besides the 7R allele, as well as other candidate genes, gene environment interactions, and epigenetics. Since testosterone is also a predictor of financial risk (Apicella et al. 2008) and testosterone levels are partly heritable, we propose that future work examine genes that influence androgen exposure.

Paper 3

Winners Don't Punish

Joint work with David G. Rand, Drew Fudenberg and Martin A. Nowak[6]

A key aspect of human behavior is cooperation (Trivers 1971; Axelrod & Hamilton 1981; Fudenberg & Maskin 1990; Binmore & Samuelson 1992; Nowak & Sigmund 1992; Colman 1995; Nowak 2006). We tend to help others even if costs are involved. We are more likely to help when the costs are small and the benefits for the other person significant. Cooperation leads to a tension between what is best for the individual and what is best for the group. A group does better if everyone cooperates, but each individual is tempted to defect. Recently, there has been much interest to explore the effect of costly punishment on human cooperation (Yamagishi 1986; Boyd & Richerson 1992; Ostrom et al. 1992; Clutton-Brock & Parker 1995; Sigmund et al. 2001; Fehr & Gachter 2002; Boyd et al. 2003; Botelho et al. 2005; Egas & Riedl 2005; Fowler 2005; Page et al. 2005; Bochet et al. 2006; Gurerk et al. 2006; Rockenbach & Milinski 2006; Denant-Boemont et al. 2007; Nikiforakis & Normann 2008). Costly punishment means paying a cost for another individual to incur a cost. It has been suggested that costly punishment promotes cooperation even in non-repeated games and without any possibility of reputation effects (Fehr & Gachter 2002). But most of our interactions are repeated and reputation is always at stake. Thus, if costly punishment plays an important role in promoting cooperation, it should do so also in a repeated setting. We have performed experiments where in each round of a repeated game people choose between cooperation, defection and costly punishment. In control experiments, people could only cooperate or defect. We find that the option of costly punishment increases the amount of cooperation, but not the average payoff of the group. Furthermore, there is a strong negative correlation between total payoff and use of costly punishment. Those people who gain the highest total payoff tend not to use costly punishment: winners don't punish. This suggests that costly punishment behavior could be maladaptive in symmetric cooperation games and might have evolved for other reasons.

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The essence of cooperation is described by the Prisoner's Dilemma. Two players have a choice between cooperation, C, and defection, D. If both players cooperate they get more than if both defect, but defecting against a cooperator leads to the highest payoff, while cooperating with a defector leads to the lowest payoff. One way to construct a Prisoner's Dilemma is by assuming that cooperation implies paying a cost for the other person to receive a benefit, while defection implies taking something away from the other person (Fig 1).

Without any mechanism for the evolution of cooperation, natural selection favors defection. But a number of such mechanisms have been proposed, including direct and indirect reciprocity (Nowak 2006). Direct reciprocity means there are repeated encounters between the same two individuals, and my behavior depends on what you have done to me (Trivers 1971; Axelrod & Hamilton 1981; Fudenberg & Maskin 1990; Binmore & Samuelson 1992; Nowak & Sigmund 1992; Colman 1995). Indirect reciprocity means there are repeated encounters within a group; my behavior also depends on what you have done to others.

Costly (or altruistic) punishment, P, means that one person pays a cost for another person to incur a cost. People are willing to use costly punishment against others who have defected (Yamagishi 1986; Ostrom et al. 1992; Fehr & Gachter 2002; Botelho et al. 2005; Egas & Riedl 2005; Page et al. 2005; Bochet et al. 2006; Gurerk et al. 2006; Rockenbach & Milinski 2006; Denant-Boemont et al. 2007; Nikiforakis & Normann 2008). Costly punishment is not a mechanism for the evolution of cooperation (Nowak 2006), but requires a mechanism for its evolution (Boyd & Richerson 1992; Clutton-Brock & Parker 1995; Sigmund et al. 2001; Boyd et al. 2003; Fowler 2005). Like the idea of reputation effects (Fudenberg 1993), costly punishment is a form of direct or indirect reciprocity. If I punish you because you have defected against me, direct reciprocity is used. If I punish you because you have defected with others, indirect reciprocity is at work. The concept of costly punishment suggests that the basic game could be extended from two possible behaviors (C and D) to three (C, D and P). Here we investigate the consequences of this extension for the repeated Prisoner's Dilemma.

104 subjects participated in repeated Prisoner's Dilemma experiments at the Harvard Business School Computer Lab for Experimental Research. Participants interacted anonymously in pair-wise encounters via computer screens. Subjects did not know how long each interaction would last, but knew that the probability of another round was 0.75 (as in (Dal Bó 2005)). In any given round, the subjects chose simultaneously between all available options, which were presented in a neutral language. After each round, the subjects were shown the other person's

choice as well as both payoff scores. At the end of the interaction, the participants were presented with the final scores and then randomly re-matched for another interaction.

We have performed two control experiments (C1 and C2) and two treatments (T1 and T2). In the control experiments, people played a standard repeated Prisoner's Dilemma. In each round they could either cooperate or defect. Cooperation meant paying 1 unit for the other person to receive 2 units (in C1 and T1) or 3 units (in C2 and T2). Defection meant gaining 1 unit at a cost of 1 for the other person. In the treatments, people had three options in every round: cooperate, defect or punish. Punishment meant paying 1 unit for the other person to lose 4. We used a 1:4 punishment technology because it has been shown to be more effective in promoting cooperation than other ratios (Nikiforakis & Normann 2008). The resulting payoff matrices are shown in Figure 1. See Appendix for more details.

Figure 1
Payoff values

A Unilateral Moves

Your move	You get	Other gets
C	$-c$	$+b$
D	$+d$	$-d$
P	$-\alpha$	$-\beta$

B Payoff Matrix

	C	D	P
C	$b - c$	$- d - c$	$- \beta - c$
D	$b + d$	0	$- \beta - d$
P	$b - \alpha$	$- d - \alpha$	$- \beta - \alpha$

C C1 and T1

	C	D	P
C	1	-2	-5
D	3	0	-3
P	1	-2	-5

D C2 and T2

	C	D	P
C	2	-2	-5
D	4	0	-3
P	2	-2	-5

A: The game is formulated in terms of unilateral moves. There is the choice between cooperation, C, defection, D, and costly punishment, P. Cooperation means paying a cost, *c*, for the other person to get a benefit, *b*. Defection means earning a payoff, *d,* at a cost, *d,* for the other person. Punishment means paying a cost, *a*, for the other person to incur a cost, *β*. B: The payoff matrix is constructed from these unilateral moves. C and D: The actual payoff matrices of our experiments.

Figure 2 shows some examples of games that occurred in the treatments T1 and T2. A number of games were all-out cooperation. Sometimes cooperation could be maintained by forgiving an opponent's defection. At other times, defection in response to defection was able to restore cooperation. Typically, costly punishment did not re-establish cooperation. In some cases, costly punishment provoked counter-punishment, thereby assuring mutual destruction. Giving people the option of costly punishment can also lead to unprovoked first strikes with disastrous consequences.

Figure 2

Games people played

	Decisions	Payoff in this interaction	Final rank
A	**Nice guys finish first**		
	C C C C	8	1
	C C C C	8	2
B	**Punish and perish**		
	C P P P P	-10	25
	D D D D D	-9	22
C	**Defection restores cooperation**		
	C D D C D C	10	15
	D D C C C C	4	9
D	**Turning the other cheek**		
	C C C C C	2	6
	D D C C C	14	19
E	**Mutually assured destruction**		
	C P P P D D	-20	30
	D D P P P P	-14	25
F	**Revenge is not so sweet**		
	C C C P D D P P P	-6	24
	C C D D D D D D D	-4	22
G	**A "preemptive strike"**		
	C P D	2	29
	C C D	-4	24

Figure 2.

There were 1230 pair-wise, repeated interactions each lasting between 1 and 9 rounds. Here are some examples (B, E and G are from T1, the others from T2.) The two players' moves, the cumulative payoff of that interaction and the final rank of each player (sorted from highest to lowest payoff) are shown. A: All-out cooperation between two top-ranked players. B: Punish and perish. C: Defection for defection can sometimes restore cooperation. D: Turning the other cheek can also restore cooperation. E: Mutual punishment is mutual destruction. F: Punishment does not restore cooperation. Player 1 punishes a defection, which leads to mutual defection.

Then player 1 is unsatisfied and deals out more punishment. G: "Guns don't kill people, people kill people". (Punishment itself is not destructive, only the people who use it.) Here, an unprovoked first strike destroys cooperation. The option to punish allows irrational people to inflict harm on the undeserving.

Comparing the two control experiments, C1 and C2, we find that the frequency of cooperation increases as the benefit to cost ratio increases. In C1, 21.2% of decisions are cooperation, compared to 43.0% in C2. For both parameter choices, cooperation is a sub-game perfect equilibrium. Comparing each control experiment with its corresponding treatment, we find that punishment increases the frequency of cooperation. In T1 and T2, 52.4% and 59.7% of all decisions are cooperation.

Punishment, however, does not increase the average payoff. In T1 and T2, we observe that 7.6% and 5.8% of decisions are punishment, P. We find no significant difference in the average payoff when comparing C1 with T1 and C2 with T2. Therefore, it here looks like punishment has no benefit for the group, which here makes it hard to argue that punishment might have evolved by group selection (Boyd et al. 2003).

Examining the data of experiments T1 and T2 on the individual level, we find no correlation between the use of cooperation or defection and payoff, but a strong negative correlation between the use of punishment and payoff (Fig 3). In experiment T1, the five top ranked players, who earned the highest total payoff, have never used costly punishment. In both experiments, the players who end up with the lowest payoff tend to punish most often. Hence, for maximizing the overall income it is here best never to punish: winners don't punish (Fig 3).

Figure 3

Punish and perish

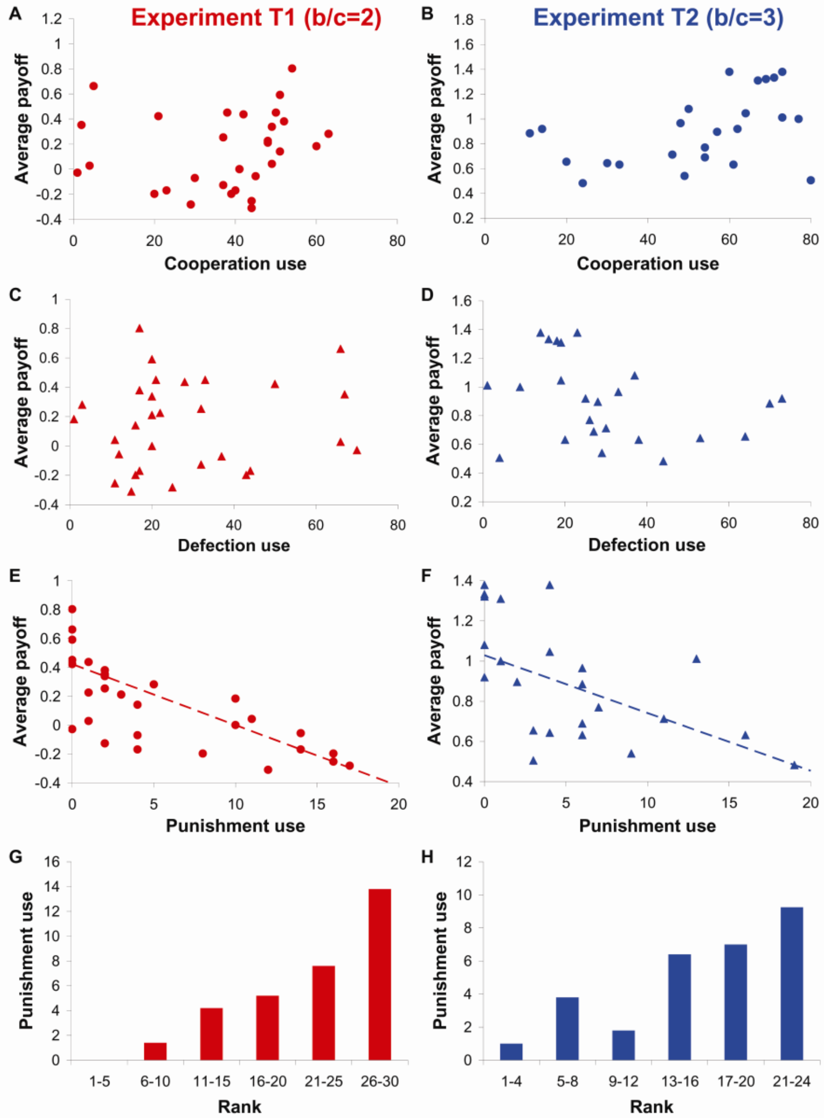

Figure 3.

In both treatments T1 (left) and T2 (right), there is no correlation between average payoff per round and (i) cooperation use (Quantile regression; A, $p = 0.33$; B, $p = 0.21$) or (ii) defection use (C, $p = 0.66$; D, $p = 0.36$). However, there is a significant negative correlation between average payoff per round and punishment use in both treatments (E, slope = -0.042, $p < 0.001$; F, slope = -0.029, $p = 0.015$). Punishment use is the overriding determinant of payoff. The x axis in panels a-f shows the total number of moves of the given type made over the course of the experiment. G and H: Ranking players according to their total payoff shows a clear trend: players with lower rank (higher payoffs) punish less than players with higher rank (lower payoff).

It could be the case that the winners of our experiment were merely lucky in that they were paired with people against whom punishment was not necessary. In order to test this hypothesis, we analyzed the correlation between payoff and the first order conditional strategies used by people. Figure 4 illustrates a strong negative correlation between payoff and the probability to use punishment, P, after the opponent has defected, D. Winners tend to respond by using D against D, while losers use P against D. The response to another person's defection is the only strategic feature which is clearly correlated with winning or losing the game. Winners play a tit-for-tat like strategy[2,4], while losers use costly punishment.

Figure 4
Tit-for-tat prevails over costly punishment

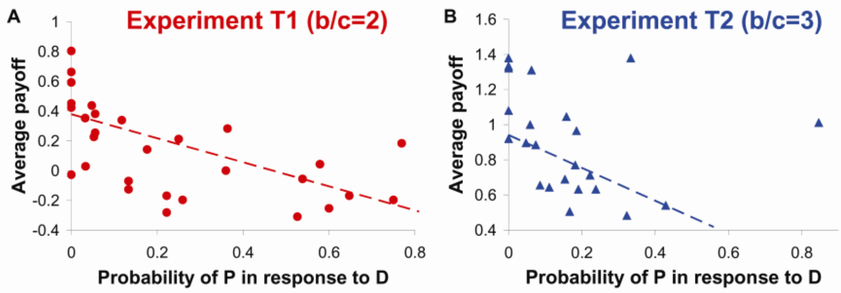

Figure 4.

Lower payoffs are correlated not only with punishment use, but specifically with choosing to punish after the opponent has defected. The probability of punishing immediately after a co-player's defection is negatively correlated with the average payoff per round, both in T1 and T2 (Quantile regression; A, slope = -0.81, p < 0.001; B, slope = -0.94, p = 0.015). Thus, the lower payoffs of punishers were not caused by the bad luck of interacting with defectors. Winners use a tit-for-tat like approach (D for D), while losers use costly punishment (P for D).

It could be that using costly punishment becomes more beneficial as the game progresses. In order to test this possibility, we have separately analyzed the data from the last ¼ of all interactions. Again, it remains true that there is a strong negative correlation between an individual's payoff and his use of costly punishment.

In previous experiments, punishment was usually offered as a separate option following one or several rounds of a public goods game. The public goods game is a multi-person Prisoner's Dilemma, where each player can invest a certain sum into a common pool, which is then multiplied by a factor and equally divided among all players irrespective of whether they have invested or not (Hardin 1968). After the public goods game, people are asked if they want to pay money for others to lose money. People are willing to use this option in order to punish those who have invested nothing or only very little, and the presence of this option has been found to increase contributions (Yamagishi 1986; Fehr & Gachter 2002).

Careful analysis, however, has revealed that in most cases, punishment does not increase the average payoff. In some experiments, punishment reduces the average payoff (Ostrom et al. 1992; Fehr & Gachter 2002; Egas & Riedl 2005;

Sefton et al. 2006), while in others it does not lead to a significant change (Botelho et al. 2005; Page et al. 2005; Bochet et al. 2006). Only once has punishment been found to increase the average payoff (Nikiforakis & Normann 2008). The higher frequency of cooperation is usually offset by the cost of punishment, which affects both the punisher and the punished. Our findings are in agreement with this observation: the option of costly punishment does not increase the average payoff of the group. It is possible, however, that in longer experiments or for other parameter values punishment does increase the average payoff.

It is sometimes argued that costly punishment is a mechanism for stabilizing cooperation in anonymous, one-shot games. But whether or not this is the case seems to be of little importance, because most of our interactions occur in a context where repetition is possible and reputation matters. For millions of years of human evolution, our ancestors have lived in relatively small groups where people knew each other. Interactions in such groups are certainly repeated and open ended. Thus, our strategic instincts have been evolving in situations where it is likely that others either directly observe my actions or eventually find out about them. Also in modern life, most of our interactions occur with people whom we meet frequently. Typically, we can never rule out 'subsequent rounds'. Therefore, if costly punishment is important for the evolution of human cooperation, then it must play a beneficial role in the setting of repeated games. Our findings do not support this claim.

We also believe that our current design has some additional advantages over previous ones. In our setting, costly punishment is always one of three options. Hence, there is an opportunity cost for using punishment, because the subject forfeits the opportunity to cooperate or to defect. Our design also minimizes the experimenter and participant demand effects (Carpenter et al. 2006), because there are always several options (Sefton et al. 2006). In many previous experiments retaliation for punishment is not possible (Ostrom et al. 1992; Fehr & Gachter 2002; Botelho et al. 2005; Egas & Riedl 2005; Page et al. 2005; Bochet et al. 2006; Gurerk et al. 2006; Sefton et al. 2006; Nikiforakis & Normann 2008), but it is a natural feature of our setting.

In summary, our data show that costly punishment strongly disfavors the individual who uses it and hence it is opposed by individual selection in cooperation games where direct reciprocity is possible. We conclude that costly punishment might have evolved for reasons other than promoting cooperation among symmetric players, such as coercing individuals into submission and establishing dominance hierarchies (Clutton-Brock & Parker 1995; Samuelson 2005). Punishment might enable a group to exert control over individual behavior.

A stronger individual could use punishment to dominate weaker ones. People engage in conflicts and know that conflicts can carry costs. It is possible that costly punishment sometimes serves to escalate conflicts, not to moderate them. Costly punishment might force people to submit, but perhaps not in all types of games to cooperate. It could be that costly punishment is beneficial in these other games, but the use of costly punishment in games of cooperation appears to be maladaptive. We have shown that in the framework of direct reciprocity, winners do not use costly punishment, while losers punish and perish.

METHODS SUMMARY

A total of 104 subjects (45 women, 59 men, mean age 22.2 years) from Boston-area colleges and universities participated voluntarily in a modified repeated Prisoner's Dilemma game at the Harvard Business School Computer Lab for Experimental Research (CLER). The lab consists of 36 computers, which are visually partitioned. The participants interacted anonymously through the software z-Tree (Fischbacher 2007) and were from a number of different schools and a wide range of fields of study; it was therefore unlikely that any subject would know more than one other person in the room. We asked subjects for their sex and major field of study. No significant difference in level of cooperation, punishment use or payoff was found between males and females, or between economics majors and non-economics majors (Mann–Whitney test, $P > 0.05$ for all sessions). Subjects were not allowed to participate in more than one session of the experiment. In all, four sessions were conducted in April and May 2007, with an average of 26 participants playing an average of 24 interactions, for an average of 79 total rounds per subject.

Each experiment was begun by reading instructions (included in the Appendix), answering two test questions to verify understanding of the payoffs, and playing a practice interaction against another subject. At the start of each new interaction, subjects were unaware of the previous decisions of the other player. After each round, the subjects were shown the other person's choice as well as both payoff scores. At the end of the interaction, the participants were presented with the final scores and then randomly rematched for another interaction.

In each session, the subjects were paid a $15 show-up fee. Each subject's final score summed over all interactions was multiplied by $0.10 to determine additional earned income. Thus, one game unit corresponded to $0.10. To allow for negative incomes while maintaining the $15 show-up fee, $5 was added to each subject's earned income at the end of the session. Subjects were informed of this extra $5 at the beginning of the session. The average payment per subject was $26 and the average session length was 1.25 h.

Winners Don't Punish

Appendix

1. Methods

A total of 104 subjects (45 women, 59 men, mean age 22.2) from Boston area colleges and universities participated voluntarily in a modified repeated Prisoner's Dilemma game at the Harvard Business School Computer Lab for Experimental Research (CLER). The lab consists of 36 computers which are visually partitioned. The participants interacted anonymously via the software z-Tree (Fischbacher 2007). The subjects were from a number of different schools and a wide range of fields of study, such that it was unlikely for any subject to know more than one other person in the room. We asked subjects for their gender and major field of study. No significant difference in level of cooperation, punishment use or payoff was found between males and females, or between economics majors and non-economic majors (Mann-Whitney test: $p > 0.05$ for all sessions). Subjects were not allowed to participate in more than one session of the experiment. A total of 4 sessions were conducted in April and May 2007, with an average of 26 participants playing an average of 24 interactions, for an average of 79 total rounds per subject.

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2. Experimental Instructions (for session T1)

Thank you for participating in this experiment.
Please read the following instructions very carefully. If you have any questions, please do not hesitate to ask us. Aside from this, no communication is allowed during the experiment.
In this experiment about decision making, you have been randomly matched with another person in the room. Neither of you will ever know the identity of the other. Everyone will receive a fixed amount of $15 for participating in the experiment. In addition, you will be able to earn more money based on the decisions you make in the experiment. The fixed amount and the money that you earn will be paid to you in cash immediately after the experiment is over.
You will interact several times with several different people. **Based on the choices made by you and the other participants** over the course of these interactions, you will receive between **$0 and $25, in addition to the $15 show-up amount.**

The Interaction:
There are **three possible options** available to **both you and the other person** in every round of the experiment: **A, B or C**. **Throughout the experiment, the person who makes a decision will consider him/herself as 'You' and consider the other person as 'The other person'**.

The payoffs of the options (**in units**)

Option	You will get	The other person will get
A:	−1	+2
B:	+1	−1
C:	−1	−4

1 unit = $0.10

If **you choose A** then **you** will get **−1 units**, whereas the **other person** will get +**2 units**.
If **you choose B** then **you** will get +**1 units**, whereas the **other person** will get **−1 units**.
If **you choose C** then **you** will get **−1 unit**, whereas the **other person** will get **−4 units**.

An experiment round is composed of two steps:

Step 1:
Both you and the other person begin by choosing one of these three options: A, B or C. There is a time limit on each decision. If you take more than 25 seconds a random choice will be picked for you, so **it is very important that you not take longer than 25 seconds.**

Step 2:
You and the other person are presented with each other's choice. Your score for round 1 will be calculated and presented to you on your computer screen. Your score in every round of the experiment is the sum of your payoff from your chosen option and of your payoff from the other person's chosen option. **Your score each round is thus determined by both your decision and the other person's decision, from step 1 and step 2.** *See the examples below for clarification*.

The number of rounds in an interaction is determined by a random mechanism. The probability that there will be another round is ¾. **Therefore, each pair will interact another round with probability 3/4.**

Your behavior will have no effect on the number of rounds. Every round will follow the same pattern of two steps. The total scores will be calculated when the interaction is finished. Thereafter, you will be **anonymously and randomly matched with another student** and will **repeat the same task again**. This change of person that you are interacting with will occur several times.

The score (number of units) that you have at the end of these interactions will determine how much money you earned in total. Therefore, the additional money you and the other persons each earn depends on which options you both choose. However, **the final scores of the other participants do not matter for your final score.**

Examples:

<u>The payoffs of the options (**in units**)</u>

Option	You will get	The other person will get
A:	−1	+2
B:	+1	−1
C:	−1	−4

If you **both choose A** then each of you will get **+1**
(-1 from yourself, +2 from the other = +1 total)

If you **both choose B** then each of you will get **0**
(+1 from yourself, -1 from the other = 0 total)
If you **both choose C** then each of you will get **-5**
(-1 from yourself, -4 from the other = -5 total)

If **person 1 chooses A**, and **person 2 chooses B** then **person 1** gets **–2** (-1 from person 1, -1 from person 2) and **person 2** gets **+3** (+2 from person 1, +1 from person 2).
If **person 1 chooses C**, and **person 2 chooses A** then **person 1** gets +**1** (-1 from person 1, +2 from person 2) and **person 2** gets **-5** (-4 from person 1, -1 from person 2).
If **person 1 chooses B**, and **person 2 chooses C** then **person 1** gets **–3** (+1 from person 1, -4 from person 2) and **person 2** gets **–2** (-1 from person 1, -1 from person 2).

Earning additional money:

In addition to the $15 show-up fee, you will begin the experiment with an additional $5. This is the base line, which corresponds to 0 game units.
Based on your decisions in this experiment, units will be added or subtracted from this initial amount. At the end of all the interactions, your total monetary payoff will be computed to determine the amount of money earned.
If you have a total score of **0** after completing all the interactions, you will have earned the additional **$5** in the experiment.
If you have a total score **above 0**, the exchange rate will be **1 unit = $0.10**. The maximum amount that you can earn will be **$25**, however, and this is rather unlikely to happen.
If you have a total score of **less than 0**, the exchange rate will be **1 unit = $0.10**, such that negative units will be withdrawn from the initial $5. However, you cannot lose more than the initial $5, so you will always walk away here with at least the **$15** show-up fee.

1 unit = $0.10

3. Supporting Figures and Data

Figure S1 shows the payoff matrices for each experiment. In all four payoff matrices the strategy Grim – start playing C and play C unless D has been played in the past – is a subgame-perfect equilibrium with the specified continuation probability of ¾.

Figure S1

Payoff matrices for each experiment

C1	C	D
C	1	-2
D	3	0

T1	C	D	P
C	1	-2	-5
D	3	0	-3
P	1	-2	-5

C2	C	D
C	2	-2
D	4	0

T2	C	D	P
C	2	-2	-5
D	4	0	-3
P	2	-2	-5

The row player's payoff is shown. Each game unit is worth $0.10

Each pairing of participants was drawn at random from the entire group. Therefore, not all interactions are independent, because some interactions share the same player. For this reason, we have not conducted our statistical analysis at the level of interactions (N between 293 and 324, depending on the session), but at the level of subjects (N between 22 and 30, depending on the session).

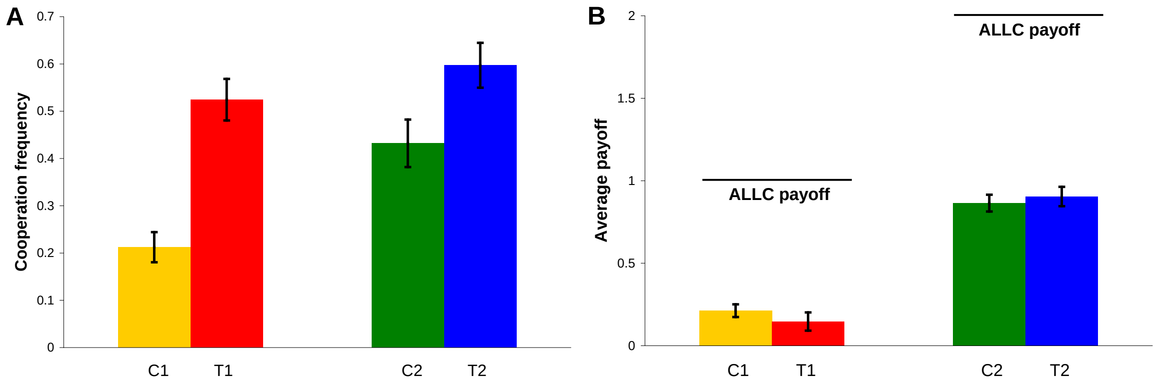
We have used quantile regression as opposed to ordinary least squares (OLS) regression in all of our correlation analyses. Quantile regression has been shown to perform better than ordinary least squares (OLS) for data with non-Gaussian error distributions (Koenker & Bassett 1978; Koenker & Hallock 2001; Cade & Noon 2003). Average payoff per decision is likely to have a non-Gaussian error distribution, as subjects using different strategies will presumably have payoffs centered around different values. Additionally, quantile regression is more robust than OLS to the presence of outliers (Koenker & Bassett 1978; Koenker & Hallock 2001; Cade & Noon 2003). For both of these reasons, a quantile regression is more appropriate here than an ordinary least squares regression for our data. Nonetheless, OLS regression with robust standard error gives similar results to quantile regression for our data. Regressing average payoff per decision against punishment use is significant, and gives a similar slope to quantile regression (T1: slope coefficient = -0.038, $p<0.001$; T2: slope coefficient = -0.031, $p<0.001$). Regressing average payoff per decision against probability to punish in response to defection is significant in T1 (slope coefficient = -.730, $p<0.001$), and significant in T2 (slope coefficient = -1.211, $p=0.04$) with the exclusion of one outlier, who has a probability to punish in response to defection more than 3 standard deviations greater than the mean. Quantile regression is less sensitive to outliers than OLS, and so does not necessitate the exclusion of any data.

Our random partner-matching method does not prevent cyclic interactions, such as A playing with B, then B playing with C, and then A playing with C. To assess whether these cycles affect our conclusion, we have examined the effect of ignoring such interactions. Excluding all interactions between A and C such that A played with B, then B played with C, and then A played with C (~55% of decisions in C1 and T1, and ~66% of interactions in C2 and T2), we still find a significant negative correlation between punishment use and average payoff per round (Quantile regression; T1 slope = -0.068, t = -2.95, p = 0.006; T2, slope = -0.086, t = -2.26, p = 0.034).

As described in the main text, the option for costly punishment significantly increases the average cooperation frequency (Fisher's Exact Test, two-tailed; C1 vs T1: $p < 0.001$; C2 vs T2: $p < 0.001$), as shown in Fig. S2A. But the average payoff per round is not significantly different between each control and its corresponding treatment (Mann-Whitney test; C1 vs T1: $z = 1.043$, $p = 0.30$; C2 vs T2: $z = -0.231$, $p = 0.82$), as shown in Fig. S2B. Therefore, punishment does not provide any advantage for the group. Additionally, the variance in payoffs is larger with punishment than without (C1, std = 14.4; T1, std = 21.5; C2, std = 20.8; T2, std =25.0).

Figure S2

Cooperation frequency (A) and average payoff per round (B) in each session



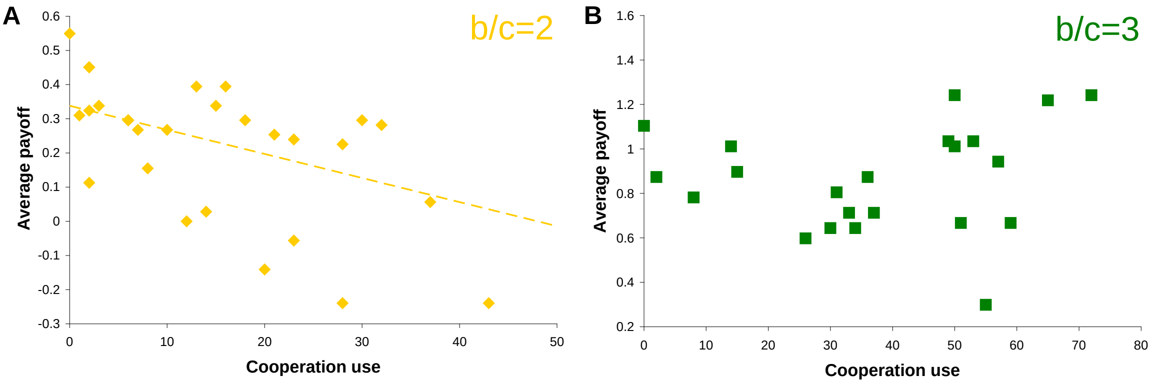
Error bars represent standard error of the mean. There is significantly more cooperation in each treatment than in the corresponding control, but no significant difference in the average payoff. All control and treatment payoffs are significantly lower than the optimally cooperative payoff for ALLC play.

In our control experiment C1 (with a b/c ratio of 2), unprovoked defection increases over the course of the session (Quantile regression, unprovoked defections occurrence against interaction number; slope = 0.5, $t = 5.06$, $p < 0.001$). This means people 'learn' to defect. In the control experiment C2 (with a b/c ratio of 3), unprovoked defection decreases over the course of the session (Slope = -0.1875, $t = -2.65$, $p = 0.014$); hence, people 'learn' to cooperate. Interestingly, in both treatments, T1 and T2, there is no significant change of unprovoked defection over the course of the session (T1: $t = 0$, $p = 1.00$; T2: $t = -1.12$, $p = 0.27$). Hence, the threat of punishment seems to reduce unprovoked defection over time when comparing C1 with T1, but not when comparing C2 with T2.

In the control treatments, the correlation between average payoff and cooperation use varies between sessions, as can be seen in Fig. S3. In C1, where the benefit-to-cost ratio is 2, a significant negative correlation exists between average payoff and cooperation use (Fig. S3A; Quantile regression; $t = -2.61$, $p = 0.015$, slope $= -0.50$). In C2, where the benefit -to-cost ratio is 3, no such correlation exists (Fig. S3B; Quantile regression; $t = 0.77$, $p = 0.452$).

Figure S3

Control Sessions

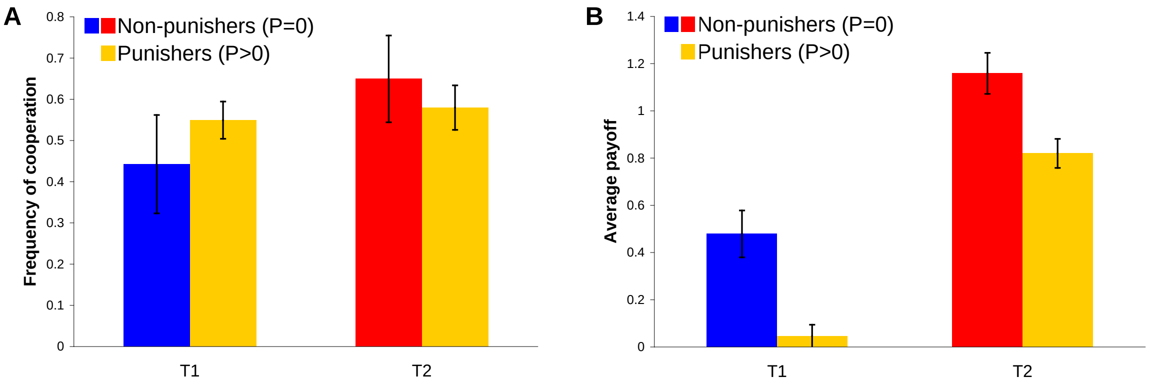


In the control sessions, the benefit-to-cost ratio affects the correlation between cooperation use and average payoff. A: In C1, where the benefit-to-cost ratio is 2, there is a negative correlation between cooperation use and average payoff. B: In C2, where the benefit-to-cost ratio is 3, no such correlation exists.

In addition to the negative correlation between average payoff and punishment use, and between average payoff and probability to use punishment in response to defection, there is further evidence that punishment use is the main determinant of payoff in the treatments. As shown in Fig. S4, punishers get lower payoffs than non-punishers, despite being equally cooperative. There is no significant difference in the frequency of cooperation between punishers and non-punishers (Fig. S4A; Mann-Whitney test; T1, $z = -0.392$, $p = 0.69$; T2, $z = 0.900$, $p = 0.37$). Punishers have significantly lower average payoffs than non-punishers (Fig. S4B; Mann-Whitney test; T1, $z = 3.262$ $p = 0.001$; T2, $z = 2.502$, $p = 0.012$). Both of these results are robust to the inclusion of players who might have "trembled" and punished only once. The fact that punishers are as cooperative as non-punishers refutes the possibility that the real difference driving payoffs is cooperation. It could be thought that non-punishers got higher payoffs because they were defectors whereas the punishers were cooperators, but this is not the case. This analysis further demonstrates that the key difference between high and low earners is the use of punishment.

Figure S4

Punishers, Cooperation and Payoffs



Punishers get lower payoffs than non-punishers, despite being equally cooperative. Error bars represent standard error of the mean. A: There is no significant difference in the frequency of cooperation between punishers and non-punishers. B: Punishers have significantly lower payoffs than non-punishers. Both of these results are robust to the inclusion of players who might have "trembled" and punished only once.

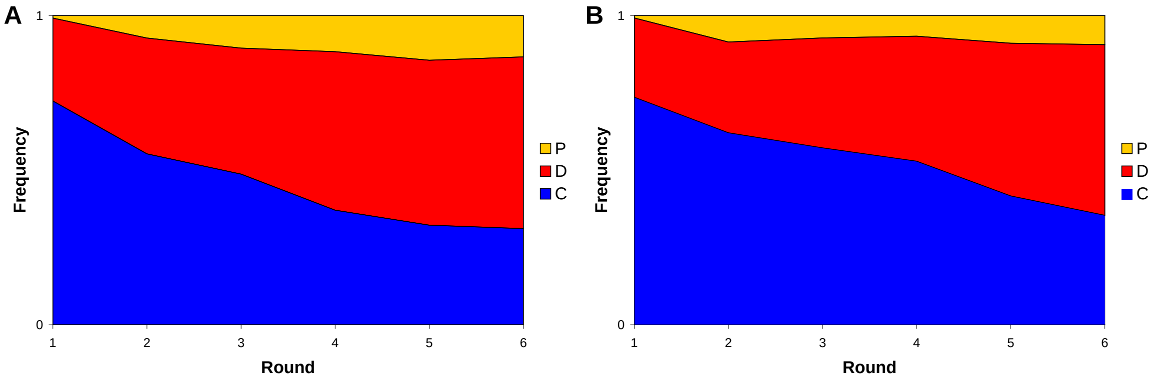
To assess the effect of experience, we have examined the last ¼ of interactions. In T1 these are interactions 15-21. In T2 these are interactions 20-27. In both treatments, there is still a strong negative correlation between average payoff and punishment use, when considering only the final ¼ of interactions (Quantile regression; T1: slope = -0.167, t = -4.85, $p<0.001$; T2 slope = -0.170, t = -4.29, $p<0.001$). Therefore, we conclude that the benefits of punishment are not increasing with experience in our experiment. Even in the last ¼ of interactions, it is the case that winners don't punish.

In the traditional approach, the 'punishment' for non-cooperative behavior is defection (Trivers 1971; Axelrod & Hamilton 1981; Fudenberg & Maskin 1990; Binmore & Samuelson 1992; Nowak & Sigmund 1992; Colman 1995; Nowak 2006). Tit-for-tat, for example, cooperates when the co-player has cooperated and defects when the co-player has defected. The proposal of strong reciprocity (Boyd et al. 2003; Fehr & Fischbacher 2003) is to use costly punishment, P, instead of defection, D, in response to a co-player's defection. Our data show that such behavior is maladaptive: winners use classical tit-for-tat like behavior (Axelrod & Hamilton 1981; Nowak & Sigmund 1992), while losers use costly punishment.

Average move frequency as a function of round in the treatment sessions is show in Fig. S5. Cooperation use decreases over the course of an interaction, while defection use increases. Although this may appear to be an effect of players inappropriately anticipating the game's end despite the constant probability of continuation each round, this is not necessarily the case. This same pattern could be explained by a constant probability to defect coupled with the tit-for-tat style response to defection.

Figure S5

Average frequency of cooperation (darkest), defection (dark), and punishment (light) over the course of an interaction, for sessions T1 (A) and T2 (B).



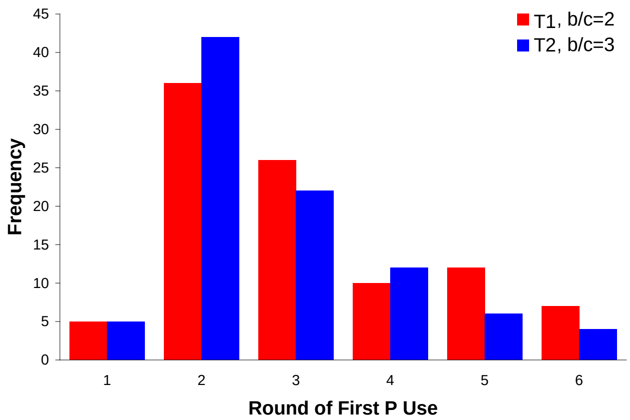
As the number of rounds increases, cooperation decreases and defection increases.

As can be seen in Fig. S6, punishment use is almost non-existent in the first round, as one would expect. In T1, punishment use increases over the course of an interaction. In T2, punishment use is essentially constant for rounds 2 to 6.

The round in which punishment is first used in a given interaction is shown in Fig. S6. Consistent with Fig. S5, punishment is rare in the first round. The first use of punishment is most likely to occur in the second round.

Figure S6

Histogram of rounds in which punishment is first used



Most often, punishment is first used during round 2, in response to the action taken by the other player on round 1.

Paper 4

Outrunning the Gender Gap – Boys and Girls Compete Equally

Joint with Emma von Essen and Eva Ranehill[7]

ABSTRACT

Recent studies find that women are less competitive than men. This gender difference in competitiveness has been suggested as a possible explanation for why men occupy the majority of top positions in many sectors. In this study we explore competitiveness in children. A related field experiment on Israeli children shows that only boys react to competition by running faster when competing in a race, and that only girls react to the gender of their opponent. Here we test if these results carry over to 8-10 year old Swedish children. We also include two more "female" sports: skipping rope and dancing. Our results contradict previous findings in two ways. First, we fail to replicate the running result. In our study, both boys and girls compete. We also find no gender differences in competition in skipping rope and dancing. Second, we find no clear effect on competitiveness of the opponent's gender, neither on girls or boys, in any of the tasks. Our findings suggest that the gender gap in competitiveness found in previous studies on adults may be caused by factors that emerge later in life. It remains to be explored whether these factors are biological or cultural.

1. INTRODUCTION

Men occupy the majority of top positions in most societies, both in the private and in the public sector. The proposed reasons for this remain highly controversial within academia as well as politics (Ceci & Williams 2006). Today, women in many countries are at least as likely as men to pursue higher education, and female labor force participation has risen to levels similar to that of men. Meanwhile, a number of recent studies show that women compete less than men.

[7] We are very grateful for comments from Johan Almenberg, Anne Boschini, Hannah Riley Bowles, Armin Falk, Magnus Johannesson, Astri Muren, Paul Nystedt, Mats Persson and David G. Rand. Financial support from the Jan Wallander and Tom Hedelius Foundation (A.D., E.R.) and the Carl Silfvén Foundation (E.R) is gratefully acknowledged, as well as financial support from Swedish Council for Working Life and Social Research (FAS).

Competitiveness is typically measured as either a preference for competition, such as self selecting into a tournament instead of a piece-rate payment scheme, or by the performance response to a competitive setting compared to a non-competitive setting. Some studies find that women's performance, contrary to that of men, depends on the institutional framework and the gender of the opponent(s) (Gneezy et al. 2003; Gneezy & Rustichini 2004; Niederle & Yestrumskas 2008; Price 2008). Other studies find that only males perform better under competition, or that when both men and women perform better, males still perform significantly better than women (Datta Gupta et al. 2005). It has also been shown that women tend to prefer the non-competitive setting even when there is no gender gap in performance in the competitive setting (Niederle & Vesterlund 2007). In some cases this implies that men compete more than what is optimal for them, and women less (Gneezy et al. 2003; Niederle & Vesterlund 2007). These gender differences have been suggested as a possible explanation for the gender gap in the labor market.

The policy implications of a gender gap in competitiveness depend on what we believe causes the gap. Apart from Gneezy and Rustichini (2004), all of the aforementioned studies look at adults. Thus, whether these gender differences are innate or acquired later in life remains unknown. Children therefore provide an interesting subject pool for the study of this distinction.

In this paper, we explore whether there are gender differences in competitiveness among children. Two previous studies investigate this. Booth and Nolan (2008) look at how 10-11 year old boys and girls from single-sex schools and from mixed schools solve simple mathematical tasks under a competitive setting (Booth & Nolen 2008). They conclude that each gender compete more in the single-sex schools than in the mixed, though boys have a higher baseline. Girls from single-sex schools choose competition as much as boys from mixed schools. In a field experiment looking at 9-10 year old Israeli children, Gneezy and Rustichini (2004) find that boys, but not girls, respond to competition by running faster against another child than when running alone. Moreover, they find that the gender of the opponent matters only for girls, who compete less when running against another girl.

We run a field experiment on 7-10 year old children in Sweden. The design is similar to that of Gneezy and Rustichini (2004), where the children compete in running. In addition, in our study the children also compete in skipping rope (where two individuals turn the rope while one child jumps) and dancing. The running task is included in order to have a direct comparison to previous work. The other two tasks are included to study whether there are male and female areas of competition. If tasks are gendered, it is possible that this leads to gender differences in both motivation for, and payoffs from, competing. Most competitiveness studies build on tasks such as solving mazes and performing simple arithmetic, which are generally considered as male tasks. Several studies show that women perform worse on standardized tests when they are reminded of negative stereotypes about female math ability (Steele 1997; Shih et al. 1999; Inzlicht & Ben-Zeev 2003; O'Brien & Crandall 2003).[8] This kind of stereotype has been suggested as one reason why women in mixed gender groups compete less than men in some of the tasks previously studied in this literature (Gneezy et al. 2003). Thus, to explore competitiveness more generally than what has previously been done, we also look at what we consider more female tasks. Since our experiment is conducted with children, our inspiration comes from tasks that children perform.

Competitiveness is measured in the same way for all three tasks. First the children perform the task individually. Their performance is measured and they are then matched together in pairs of two depending on their result. Thereafter the children perform the task a second time in these matched pairs. Competitiveness is measured as the difference in performance between the individual and matched performance.

Given previous literature, we hypothesize that if there is a gender gap in running, boys will compete more than girls. We also hypothesize that if there is a gender gap in the female tasks it will be the opposite since, if anything, these tasks have positive stereotypes regarding female ability.

In our study we find no evidence in support of our hypotheses. We find no gender differences in competitiveness among children in Sweden. We thus fail to replicate the finding of (Gneezy & Rustichini 2004), who found that only boys competed. By contrast, we find no gender difference in running or in the two other tasks. Boys and girls increase their performance in the competitive setting for running and skipping rope, and there is no difference between the average increases. Regarding the dancing task, both boys and girls decrease their performance when competing, possibly due to attempts of imitating the other child.[9] However, this decrease in performance is not significantly different between the two genders. Our results also indicate that the gender of the opponent does not alter performance of either gender in any of the three tasks.

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[8] Interestingly when women are told that there are no differences between men and women in abstract math tests, women perform as well as men (Spencer et al. 1999).

[9] Hannah Riley Bowles pointed out to us that dancing is often a cooperative or communal activity. This aspect of dancing might explain why the children were imitating one another in the competitive stage.

It has previously been shown that cultural factors may influence competitive behavior (Gneezy et al. 2008). Comparing a matrilineal society in India with a patriarchal society in Tanzania, women are found to prefer the competitive setting more than men in the matrilineal society, whereas the inverse is found in the patriarchal society.[10] Our results also suggest that cultural factors matter. Even though Sweden and Israel are both Western societies with high female labor force participation, Sweden usually performs higher on gender equality indices.[11] Thus, results on the running task deviating from those presented in Gneezy and Rustichini (2004) point to cultural factors playing an important role in competitiveness also among Western countries.

Our paper is organized as follows. In section 2, we describe the experimental design of our field study. In section 3, we present our results. We conclude in section 4, where we also discuss the possible explanations for our findings as well as promising directions for future research.

2. EXPERIMENTAL DESIGN

The field experiment was conducted in 9 primary school classes in the Stockholm area in the spring of 2008. All tasks were performed during physical education classes and the experiment was overseen by the teacher. The children, all aged 8-10 years old, did not realize that they were participating in an experiment: the tasks are standard in Swedish physical education classes. On two or three different occasions, the children competed in running, skipping rope and modern dance. These three tasks were carefully chosen. Running has previously been explored in Gneezy and Rustichini (2004) and is part of physical education in Sweden. Skipping rope is a task that girls perform during school breaks throughout the world, including Sweden. Dancing is often considered female (Henschel-Pellet 2001), and during the Swedish school year it typically takes up one physical education class. The running task was administered by the teachers on a separate occasion, whereas the skipping rope was instructed and administered by the experimenters as an exercise complementary to the dancing. The dancing task was designed, instructed and scored by a professional dance teacher on one or two

[10] The task at hand is the toss of a tennis ball into a bucket. Gneezy et al. (2008) are unaware of any resemblance between this task and some popular task in the cultures that are being studied, thus it is unlikely that the specific task had a certain gendered stereotype. In general, however, throwing objects could be considered more male in many cultures since men have typically been the hunters (e.g., men hunt through spear throwing).

[11] The Global Gender Gap Report 2007 lists Sweden as the most gender equal country in the world. Israel ranks 36th out of 128 countries.

occasions depending on the length of the class. All teachers, including the dance teacher, were unaware of the gender perspective of the study. The children were given some time to practice the dancing and the skipping rope tasks prior to the start of the experiment.

Competitiveness was measured in the same way in all three tasks. Each task consisted of two stages. At the first stage, the children performed the task by themselves and individual performance was measured. At the second stage, the children performed the task in competition with another child. The children knew that their competitor had achieved a similar score at the first stage. If more than two children obtained the same result in the first stage, matching was done randomly.[12] In running, the children were scored based on how fast they ran 60 meters. In skipping rope, performance was measured as the number of jumps performed. In dancing, the dance teacher scored the children based on how they performed compared to the set goal of the dance choreography. The dance choreography included ten distinct exercises and the children were awarded one point for each of these ten movements that they performed correctly.[13] Our measure of competitiveness is the change in performance between the first and the second stage of the tasks.

The dance teacher presented the tasks as competitive activities. The dance competition was presented as a "battle", in the spirit of a popular TV show.[14] For the skipping rope task, two ropes were put next to each other. The children were instructed to start jumping at the same time and were told that the winner was the child who performed the greatest number of jumps. All rules were explained by the dance teacher and the experimenters and no compensation was awarded apart from the intrinsic motivation that comes from winning, as in Gneezy and Rustichini (2004).

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[12] When an unequal number of children performed equally well, they were randomly paired. The remaining child was matched with the child with the next best result. If more than one child had the next best result, the remaining child with the higher score from the first matching was randomly matched with one of these children. During the competitive part of the experiment, the competing pairs participated in random order.

[13] The dance task consisted of a one minute long modern dance phrase. The choreography of the phrase was chosen to be as gender neutral as possible, focusing on strength, coordination and balance rather than "feminine grace". There is an element of subjectivity in the evaluation of dance. Since the dance teacher was not aware of the purpose of the study, we hope that this subjectivity is orthogonal to the gender of the child evaluated.

14 The TV show "So you think you can dance" was aired on Swedish television during the time the study was performed. In the show, participants dance pair-wise in competition and are eliminated based on their relative performance within the pair. We expect this TV show to have decreased the cooperative or communal aspects of the dancing task, if anything.

3. RESULTS

Previous literature (Gneezy et al. 2003; Gneezy & Rustichini 2004) found gender differences in performance in a non-competitive versus a competitive setting, as well as differences in reaction to the gender composition of the competing pair. We test whether these two results hold for children in Sweden and whether the nature of the task affects the size and direction of the gender gap. We start by looking at gender differences in competitive behavior. We then address the effect of the gender composition in the competitive setting. For all tests in the analysis, we have performed a Mann-Whitney test, a two-sided t-test and used bootstrap techniques. Throughout the analysis we present only the p-value for the Mann-Whitney test[15].

3.1 No Significant Gender Differences in Competitive Behavior

In our study, 149 children participated in running, 143 in skipping rope, and 146 in dancing. The gender distribution in the three sports was 71 boys and 78 girls in running, 69 boys and 74 girls in skipping rope and 64 boys and 82 girls in dancing.[16] Table 1 below shows that in all three tasks, and for both genders, average performance in the competitive setting differs significantly from average performance in the non-competitive setting, ($p<0.01$). Both genders improve significantly in running and skipping rope in the competitive setting, but perform worse in dancing. In the individual setting (stage 1) boys ran on average faster than girls, and girls skipped and danced better compared to boys. In running, the p-value for a significant gender difference is 0.0040, in skipping 0.0151 and in dancing 0.0478. Consistent with sex-stereotypic expectations, boys did better in the individual setting of running and girls did better in the individual setting of skipping rope and dancing.

[15] We present the Mann-Whitney test since none of our variables are normally distributed when using a skewness and kurtosis test. When there is a difference between the tests in terms of significance we also report the p-values for the t-test and the bootstrap-based critical values.

[16] Two subjects, one boy and one girl, were dropped from the sample due to physical disabilities. The differences in number of children between activities are due to the fact that we had different number of occasions depending on the structure of the physical education classes in the different schools. There is no significant difference in performance change between school classes that had one occasion or school classes that had more occasions ($p=0.44$).

Table 1

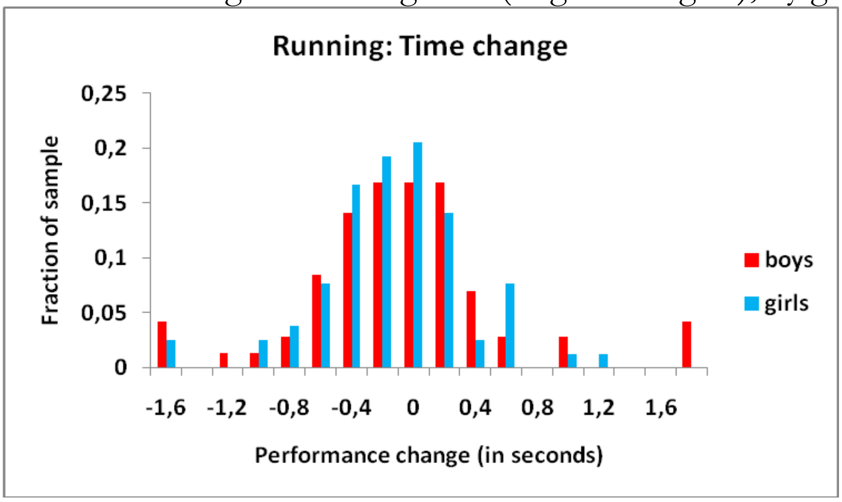
Average performance in stage 1 and in stage 2. Signrank test p-values of performance change for girls and boys separately

	Running		**SR**	**Skipping rope**		**SR**	**Dancing**		**SR**
	Stage 1	Stage 2	p-value	Stage 1	Stage 2	p-value	Stage 1	Stage 2	p-value
Girls	11.948	11.688	0.000	48.851	69.405	0.000	5.866	5.134	0.001
Boys	11.534	11.396	0.001	33.130	45.783	0.004	5.266	4.484	0.001

Figures 1-3 below show the distribution of the performance change in the different tasks. The three histograms indicate that girls tend to improve their performance slightly more in running and skipping rope, and deteriorate slightly less in dancing. However, these gender differences are far from statistically significant (running: p=0.53, skipping rope: p=0.23, dancing: p=0.85).[17]

Figure 1

Distribution of change in running time (stage 2 - stage 1), by gender



[17] To further investigate a possible gender difference in performance change we also performed quantile regressions for each task, controlling for gender of opponent (performed for quantile 0.1-1.0). Gender has an effect only in the top 10% of the performance change distribution in running and skipping rope. In this part of the distribution the performance change of boys is larger than girls in running and the opposite for skipping rope.

Figure 2

Distribution of change in jumps (stage 2 – stage 1), by gender

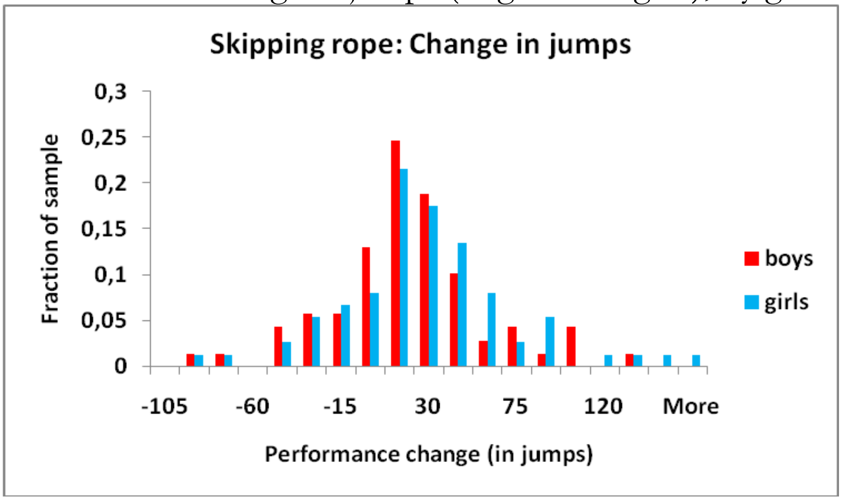
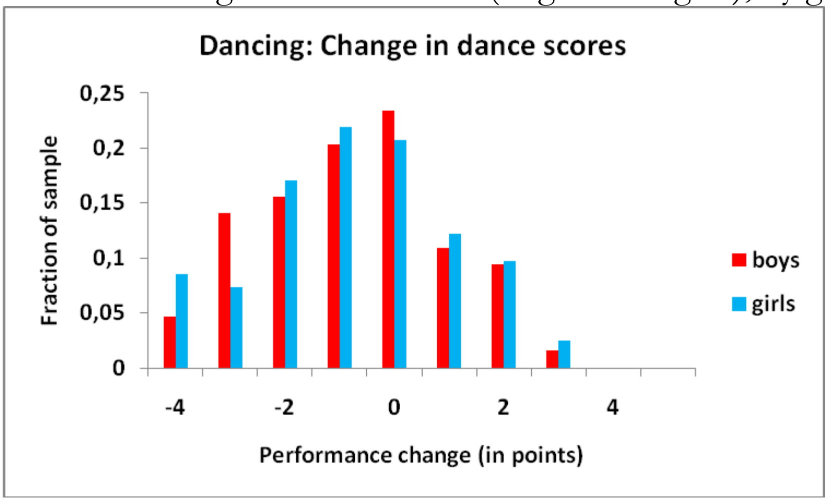


Figure 3

Distribution of change in dance scores (stage 2 – stage 1), by gender



The pattern of gender similarities are displayed in an aggregated manner in figures 4-6 below. These plots show the average change in performance by each gender. The point estimate indicates that girls increase their performance more than boys in both running and skipping rope. In running, girls improve on average 0.26 seconds, or about 2.2%. This can be compared to the average decrease in running time of 0.14 seconds, or 1.2%, for boys.[18] The corresponding numbers for skipping rope is an increase of 21 versus 13 jumps, implying an improvement of 38% and 42% respectively. The point estimate for dancing indicates that competition is less detrimental to the performance of girls than boys. On average,

[18] We conducted the same analysis with relative performance, where relative performance was defined as ((race2-race1)/race1). This did not change any of our results. Our findings further remain stable when excluding outliers. An outlier is defined as an observation that lie more than two standard deviations away from the sample mean.

boys dance performance deteriorates by 0.78 points (15%) on average and girls by 0.73 points (12%). However, as stated above and as indicated by the error bars, the difference in average change in performance between boys and girls is not statistically significant in any of the three cases.[19] These results also hold within all age groups in our sample.

Figure 4

Average change in time (stage 2 – stage 1), by gender. The error bars indicate 95% confidence intervals for the mean. 78 girls and 71 boys

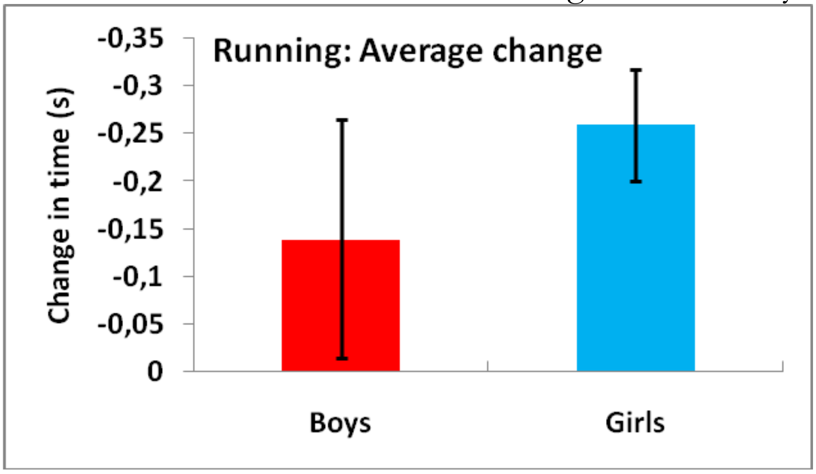
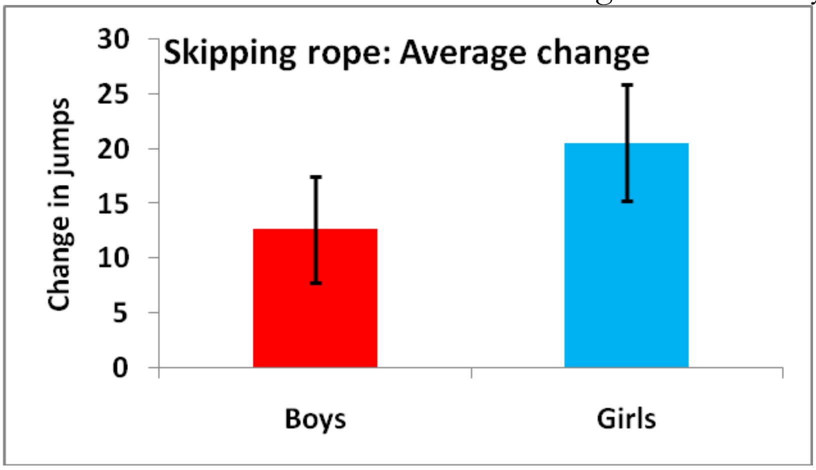


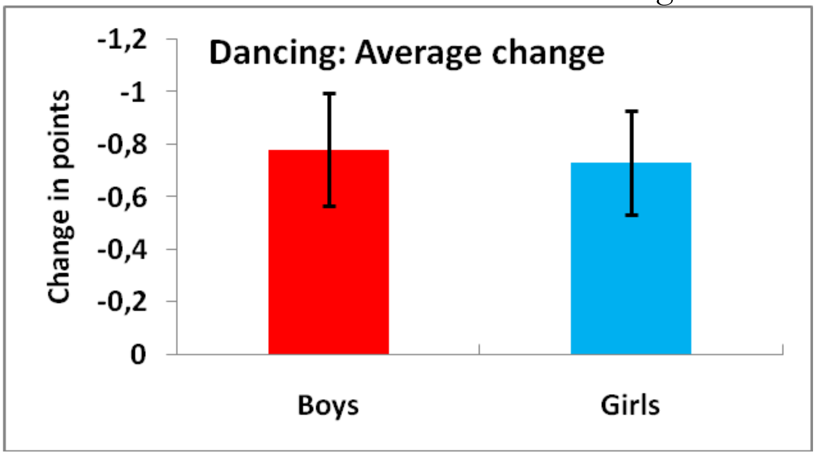
Figure 5

Average change in jumps (stage 2 – stage 1), by gender. The error bars indicate 95% confidence intervals for the mean.74 girls and 69 boys



[19] A power analysis indicates that 750, 450 and 20000 observations would be needed to obtain a significant result for the running, jumping and dancing respectively. The basis for the power calculation is a significance level of 5% and a power of 80%.

Figure 6
Average change in dance scores (stage 2 – stage 1), by gender. The error bars indicate 95% confidence intervals for the mean. 82 girls and 64 boys



3.2 Impact of Opponent Gender on Competitive Behavior

Previous studies find that women compete more against women, and men more against men (e.g., (Gneezy et al. 2003; Datta Gupta et al. 2005)). On the contrary, Gneezy and Rustichini (2004) find that boys are not affected by the gender composition but girls compete more against boys. Our results suggest that girls are not influenced by the gender of their opponent. For boys, the results are inconclusive.

Table 2 gives an overall summary of our results for the different pair compositions. In running, both girls and boys improve the most when running against a girl. However, the difference in competitive behavior for girls when facing the same vs facing the opposite gender is small and statistically insignificant (p=0.43). For boys the (Mann-Whitney) p-value is 0.0357, indicating that boys respond to the gender of the opponent in running, competing more fiercely against a girl. However, the parametric t-test and the bootstrap-based critical values show no significance. The difference between these three tests could be a result due to extreme observations (outliers) in the sample. Running the same tests when excluding observations more than two standard deviations away from the sample mean reveal a consistent significant difference in how boys respond to gender composition. Assuming that running is a male stereotyped task, one plausible explanation to this result could be that boys experience more confidence of winning if they face a girl.

In skipping rope and dancing girls compete more fiercely against boys, but none of these results are significant (skipping rope: p=0.2111, dancing: p=0.4982). Boys on the other hand compete more against boys in skipping rope and more against girls in dancing, though these differences are not significant (skipping rope: p=0.7907, dancing: p=0.4519).

Table 2
Performance change (stage 2 – stage 1) based on the gender composition of the competing pairs

	Run			Jump			Dance		
Sample	**n**	**Stage2-stage1**	**p-value**	**n**	**Stage2-stage1**	**p-value**	**n**	**Stage2-stage1**	**p-value**
Total	149	-0.20	0.000	143	17	0.000	146	-0.75	0.000
Girls	78	-0.26	0.000	69	21	0.000	82	-0.73	0.001
Boys	71	-0.14	0.001	74	13	0.004	64	-0.78	0.001
Girls with girls	45	-0.27	0.001	39	14	0.031	41	-0.83	0.002
Boys with boys	43	-0.12	0.192	31	15	0.010	27	-0.96	0.005
Girls in mixed pairs	33	-0.25	0.002	35	27	0.001	41	-0.63	0.079
Boys in mixed pairs	28	-0.16	0.000	38	10	0.122	37	-0.65	0.054

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3.3 Robustness Checks

We also let a separate group of children perform the task alone in the second stage, serving as a control group. We thereby control for unobservable factors that could cause differences in the outcome, such as one gender getting tired faster than the other. The control group includes 33 children. The absolute performance between stage 2 and stage 1 in skipping rope and dancing is not significant (skipping rope: p=0.1205, dancing: p=0.4804). This indicates that when not competing against another child there is no significant improvement in performance. Moreover, we find no significant differences when testing performance change between genders (skipping rope: p=0.7200, dancing: p=0.6312).

Even though we find no significant differences in mean change in performance in our main analysis, there may be differences in the variances of the performance distributions. We control for this, and find no significant differences in the variance of change in performance between girls and boys.[20]

[20] The most common test for comparison of standard deviations is very sensitive to the assumption that that the data are drawn from an underlying normal distribution. Therefore we also performed a robust test (Levene's test with mean, median and 10% trimmed mean). None of these tests indicated significant differences in the variances.

4. CONCLUSION

Previous literature on competitive behavior finds that men compete to a larger extent than women. This difference in behavior may explain part of the gender gap observed in many areas in society. In this literature, however, only a few tasks have been used to measure competitiveness, and these tasks can arguably be considered as more male than female. As far as we know, no previous study investigates whether the gender gap is reversed in other types of tasks. Meanwhile, work in social psychology suggests that individual perceptions about relative performance, such as (over)confidence, and especially stereotypes may have important implications for actual performance (Steele 1997; Shih et al. 1999). Exploring more tasks than maze solving and simple arithmetic is thus important in order to increase our understanding about gender differences in competitiveness and the potential role of stereotypes.

In this paper we study how children compete in three distinct tasks. We let the children compete in running in order to create a comparison with previous literature. Moreover, we add two more “female” tasks to the competition; skipping rope and dancing. Competitiveness is measured as the child’s increase in performance when competing against another child, compared to when the task is performed individually. We find no gender differences in competitive behavior in any of these tasks. Boys respond to competitiveness, and so do girls. Contrary to previous literature (Gneezy et al. 2003; Gneezy & Rustichini 2004; Datta Gupta et al. 2005) we also find no conclusive evidence that the gender of the opponent affects boys or girls in any of the three tasks.

Making inferences about adult behavior from findings on children is not straightforward. Even though we do not find a gender gap among children in Sweden, it may be that men’s and women’s behavior change differently over time. This could be due to socialization, biological factors, or some mix of the two. Thus, observing gender diversity in behavior among adults does not tell us the underlying reasons for these gender differences. For example, if a gender gap in behavior occurs during the teenage years, this could be caused by socialization or by the hormone surge that puberty brings along. However, a study looking at competitiveness among men find that the propensity to choose a tournament over a piece-rate scheme does not correlate with hormonal (Dreber et al. Unpublished manuscript).[21] Whether hormones affect competitiveness in women remains

[21] Neither circulating testosterone nor digit ratios (considered a proxy of prenatal hormone exposure) correlate significantly with competitiveness. There is some evidence of facial masculinity (considered a proxy of hormone exposure during puberty) being at best a marginally

unexplored, but recent evidence suggests that exogenously providing estrogen and testosterone to women does not affect their economic preferences (Zethraeus et al. 2009).[22]

Our results also add to the literature on how culture influences economic behavior. It has previously been shown that culture affects important economic decisions such as labor market participation and fertility (Fernández & Fogli 2006). The institutional setting has been found to influence competitive behavior (Gneezy et al. 2008; Niederle & Yestrumskas 2008). For example, women have been found to compete more than men in a matrilineal society whereas men compete more than women in a patriarchal society (Gneezy et al. 2008). Even though our study only includes children in Sweden, we can compare our running results to those of Gneezy and Rustichini (2004). Where we find no gender gap, Gneezy and Rustichini (2004) instead find that among Israeli children only boys respond to competition in a running task. It is possible that the more gender neutral culture in Sweden decreases the difference in competitive behavior between boys and girls in general, but also that it diminishes the degree to which tasks are gendered. If this is the case, this could explain why boys and girls compete equally in all tasks in our study.

Our findings open up interesting avenues for further research. If competitive behavior among boys and girls is task dependent, competitive behavior should be studied in a variety of tasks and cultural settings. Since we find no gender differences among children in Sweden, it would also be of great interest to see if there is a gender gap in competitiveness among Swedish adults, and if so at what age this first occurs. Once we have answers to these questions it will be possible to make more general claims about gender and competitiveness, and possibly how and if this relates to labor market outcomes.

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significant predictor of competiveness, but this result is not very robust for the inclusion of other variables.

[22] However, it could be the case that it is the long-term organizational effects of hormonal exposure that matter and not the effects from short-term exposure.

Paper 5

Lady and the Trump: Status and Wealth in the Marriage Market

Joint work with Johan Almenberg[23]

ABSTRACT

We examine a relatively neglected aspect of intergenerational transmission of economic standing, namely culturally determined status markers and their valuation in the marriage market. We take nobility to be such a status marker. Using data on Swedish marriages, we test the hypothesis that nobility have a greater probability of marrying "up" in terms of wealth. We find a large and statistically significant positive effect for nobility. This finding has implications for the intergenerational transmission of inequality, and for the longevity of the institution of nobility itself.

1. INTRODUCTION

If wealth begets wealth, dynasties may endure even in otherwise meritocratic societies. And if an indicator of past wealth begets wealth, this too will reinforce the persistence of economic standing across generations. Such indicators typically bestow prestige and contribute to high status. Nobility, a culturally determined (i.e., non-genetic) hereditary status marker, might act as such an indicator, and thereby serve as a vehicle for the cultural transmission of economic standing. A wide range of channels besides the traditional economic variables have previously been found to be incorporated in the intergenerational transmission of economic standing. For example, heritability of physical traits, such as cognitive ability and health, and physical appearances, such as height, attractiveness, and race, have all been found

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to affect economic outcomes (see, e.g., (Hamermesh & Biddle 1994; Bowles & Gintis 2002; Tao 2008)). While cultural transmission of economic standing clearly also plays a part, this vehicle has so far remained relatively unexplored.

Nobility as an institution is an anachronism: it is a traditional term for the highest social class in some pre-modern societies. Status, however, plays an important role in most societies and in most times, making individuals allocate valuable resources to status-enhancing activities. This suggests that even though nobility no longer entails formal privileges, it may continue to be coveted as a status marker.

Anecdotal evidence suggests that nobility has retained its allure in the modern age. John von Neumann, the mathematician who pioneered the expected utility framework and laid the foundations of modern game theory, was the son of Max Neumann, who in 1913 purchased a claim to Austrian nobility. Max Neumann thereby acquired the right for his offspring (but not for himself) to call themselves von Neumann, a right of which his son John made good use.[24] Another example is German industrialist Heinrich Thyssen, who married the Hungarian baroness Margit Bornemisza in 1906. Thyssen, a commoner, had his father-in-law adopt him, and since the Baron had no male heirs, Emperor Franz Joseph I bestowed on Thyssen and his descendants the right to adopt the Bornemisza name, coat of arms, and title of Baron. More recently, a scandal erupted in the UK in 2006 following indications of a correlation between individuals making large loans on favorable terms to the Labour party, and subsequent nominations for peerage.[25]

We examine the relative performance of nobility in the marriage market. In doing so, we seek to fuse research on status with research on mating patterns. Our enquiry rests on two implicit assumptions: (1) nobility bestows status on the beholder; and (2) individuals get utility from status, either directly or indirectly. Nobility is typically not traded in open markets, making it difficult to observe its price. We argue that the marriage market might serve as an informal conduit for such transactions. If nobility is a vehicle for the intergenerational transmission of economic standing, the marriage market is the mechanism for this transmission. If such indirect trade occurs, we ought to be able to observe the valuation of nobility in this market.

The Swedish marriage market provides us with an opportunity to estimate the valuation of nobility. In Sweden, nobility as an institution originates from the Alsnö Rules of 1280, which granted landowners exemption from taxation in exchange for

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[24] By contrast, von Neumann's contemporary Friedrich von Hayek was *bona fide* nobility but preferred to omit the *von* and simply call himself Friedrich Hayek.
[25] These peerages are not hereditary.

supplying the monarch with cavalry troops (vassalage). During the Middle Ages, the link between vassalage and membership of the nobility became weaker. Increasingly, noble titles came to be handed out at the monarch's discretion, and it is these titles that have come to constitute the institution of nobility in its present form. The vast majority of the nobility was created in the period 1611-1718, a period of more or less continuous warfare. The last time Sweden entered into war was 1814. In the ensuing peacetime, the creation of nobility declined rapidly. During the 19th century, the monarch's right to hand out noble titles was increasingly questioned. The nobility lost most of their formal privileges in the reform of 1809, and their political influence was greatly reduced through the reform of 1866, in which the House of Nobility was stripped of its role as upper chamber of Parliament. In 1975, the monarch's right to hand out noble titles was formally revoked.[26] Today, Swedish nobility enjoy no formal privileges. Swedish law does not permit transferring ownership of a claim to nobility in an open market. Marriage is the only remaining conduit for those seeking to join the nobility. In sum, nobility is an asset that conveys no material privilege and cannot be traded in an open market.

An old Swedish custom enables us to identify members of the nobility in our marriage data. Beginning in the mid-16th century, it became customary for newly created nobility to take a new, distinct name upon becoming part of the nobility, often using a familiar set of prefixes and suffixes.[27] Moreover, Swedish law awards intellectual property rights to surnames in direct relation to how distinct they are, i.e., in inverse proportion to the number of families sharing the name. As a consequence, noble names enjoy particularly strong protection and are easily identifiable. The House of Nobility in Stockholm publishes an annual directory of the members of the approximately 600 remaining noble families. Combining the records of the House of Nobility with the Total Population Register compiled by Statistics Sweden enabled us to generate a unique data set, consisting of repeated cross-sections of all marriages in Sweden in 1985, 1990, 1995, 2000 and 2004. In addition to information about the age, education, income and wealth of both spouses, the data also contains an indicator showing if an individual's surname denotes nobility.

Our data set provides an opportunity to examine whether people are willing to trade wealth for status, by testing the hypothesis that the probability of

[26] At that point, this right had not been exercised in a long time: the last individual to join the ranks of nobility was the explorer Sven Hedin, in 1902.

[27] A few noble families bear common names (i.e., names that are not distinct). If there are individuals in our data set that have mistakenly been identified as nobility, this might result in a slight downward bias in our estimates.

hypergamy (marrying "up") in terms of wealth increases when an individual belongs to the nobility. If nobility bestows status, and if individuals value both status and material consumption, we would expect an individual belonging to the nobility to attain a premium in the marriage market compared to a non-noble individual with otherwise identical characteristics. Such mating patterns would be consistent with complementarities between wealth and status.

We also test the auxiliary hypothesis that male nobility is valued more than female nobility. To the extent that individuals care about their offspring, they will attach greater value to a status marker if it can be passed on to their children. Swedish nobility is hereditary on the male side only. Conditional on a continued male lineage, noble status can be thought of as an asset that continues to pay dividends indefinitely. Even with intergenerational discounting, we would expect such an asset to attain a higher price than the non-hereditary equivalent, which can be thought of as an asset paying a dividend only in the current period.

Our main finding is a significant increase in the probability of hypergamy in wealth for members of the nobility, controlling for own wealth and other covariates. This nobility premium is sizeable. The wealth distribution in our data is heavily concentrated in the lowest wealth bracket, resulting in a low baseline probability of marrying up. Given this, the observed nobility premium must be considered large, increasing the probability of marrying up by about 40 percent. The effect is statistically significant and robust to a number of different measures of hypergamy.

We find less support for the auxiliary hypothesis that male nobility attain a higher premium than female nobility. The interaction term for male sex and nobility has the expected (positive) sign, but is not statistically significant. In other words, we are unable to reject the hypothesis that the premium is of equal magnitude for male and female nobility.

In sum, our main finding is consistent with the hypothesis that nobility attain a premium on the marriage market, indicating that mate preferences are status sensitive. Our results are highly robust to different definitions of hypergamy. This suggests that the cultural transmission of economic standing, channeled through nobility and other status markers, should be taken into account in an analysis of the intergenerational transmission of inequality.

Our paper is organized as follows. In section II, we outline some relevant existing research on status and marriage. In section III, we describe our marriage data. In section IV we present our econometric model and report the regression estimates based on the marriage data. We also summarize our robustness checks.

We conclude in section V, where we discuss some implications of our results and suggest directions for future research.

2. RELEVANT LITERATURE

Our analysis draws on two strands of economic research: on the one hand, literature looking at the role of status in the economy, and on the other hand, the economic analysis of the "marriage market", i.e., the matching of brides and grooms. In this section we outline some of the more relevant literature in these areas.

2.1 Status

That the concern for relative position plays an important role in social interactions is by no means a recent insight in economics. Adam Smith devoted a considerable part of *The Theory of Moral Sentiments* to a discussion about the link between wealth and social esteem (Smith 2000).[28] Veblen ((Veblen 1899), pp. 25-26) famously argued that the pursuit of relative position is the main driving force of (conspicuous) material consumption:

> The motive that lies at the root of ownership is emulation; and the same motive of emulation continues active in the further development of the institution to which it has given rise and in the development of all those features of the social structure which this institution of ownership touches. The possession of wealth confers honour; it is an invidious distinction.

This raises the question of whether relative position is pursued as an end in itself. Some researchers argue that humans may well be hardwired to seek gratification from moving up in the social hierarchy (Frank 1999). Frank points to research showing that relative position is correlated with serotonin levels in non-human primates (McGuire et al. 1982; Raleigh & McGuire 1994).

If individuals derive utility from status in itself, independently of material benefits associated with it, a utility function that incorporates relative position as one of its arguments might do a better job of explaining individual choices (see, e.g., (Frank 1985; Huck & Müller 2000)). The idea of status in the utility function has recently been picked up by Becker et al. (2005, p. 283), who note that "[w]hen

[28] See in particular chapters 2 and 3.

status is important, individuals would be willing to pay a lot in time, effort, and money for sufficiently high status." Utility derived from relative position in itself has also been analyzed in theoretical work on incentives (see, e.g., (Moldovanu et al. 2007)). A closely related discussion can be found in an analysis of the supply of, and demand for, awards such as medals, orders and decorations, with the emphasis on their role as status markers (Frey 2006). Another related strand of research takes identity, of which status may be an important determinant, as an argument of the utility function (Akerlof & Kranton 2000).

To the extent that other individuals attach a value to relative position, status markers may have economic value even to individuals who do not care about relative position in itself. In a laboratory experiment, it has been found that economic outcomes are affected by the status of participants in a market (Ball et al. 2001). Individuals who were assigned high status attained higher prices as sellers, and lower prices as buyers, than individuals who had been assigned low status. This effect prevailed even when the assignment of status was entirely random, and the randomization process was common knowledge. Such behavioral patterns would allow individuals to reap direct economic benefits from status markers. Hence they may covet these without necessarily getting any utility from the status marker in itself. We return to this important qualifier in section 2.3.

2.2 The Marriage Market

We hypothesize that individuals with wealth but no status are likely to be matched in marriage with individuals with status but less wealth. Such a mating pattern is assortative, in the sense that individuals are sorted non-randomly into matched pairs on the basis of observable characteristics. Most animals engage in assortative mating. The most commonly observed pattern is positive assortative mating, meaning that a member of a species is matched with another member of that species who is similar with regard to a certain trait. Compared to less stratified mating patterns, positive assortative mating reinforces differences in the endowments of biological, economic and cultural assets in the population over time (Fernández & Rogerson 2001; Fernández et al. 2005). Under certain assumptions, such mating patterns can preserve heterogeneity in a population indefinitely (Bisin & Verdier 2000).

The seminal microeconomic model of assortative mating in the marriage market is Becker (Becker 1973, 1991). This model, originally introduced in a paper to describe the assignment of plants to locations, generates a pairwise assignment of elements of one set to elements of another set (Koopmans & Beckmann 1957). The elements of a set differ in a single trait. In Koopmans and Beckmann (1957), an optimal sorting is defined as a sorting that is in the core, in the sense that there is no other coalition outside the core in which both parties could be made better off by an alternative sorting. A key result in this model is that such a sorting necessarily produces the greatest aggregate output (summing across all matches), though it does not necessarily include the largest output element (the matching with the largest output).

Becker's adaptation of the Koopmans and Beckmann model to the marriage market hinges on his characterization of marriage as an economic institution. Central to his analysis is the idea of a marriage production function, which takes the endowments (in a wide sense) of both spouses as its inputs, and produces a joint output that is consumed by the household. This joint output consists of pecuniary rewards from the labor market, non-pecuniary production taking place at home, and leisure. The model is unitary, in the sense that the household is assumed to maximize this output according to a single utility function, which does not require explicit modelling of the bargaining for resources within the household.

In Becker's (1973) model, individuals differ in a single trait, common to both men and women, and a marital output function that is increasing in this trait. The model predicts positive assortative mating in this trait if an increase in the trait for both partners has an effect on marital output that is greater than the sum of the partial effects of increasing one while holding the other constant. In other words, increasing the trait in one partner raises the marginal effect of the other partner's endowment of the trait on marital output. In economic terms, there is *complementarity* between the two partners' endowments of the trait. In the presence of such complementarity, it can be shown that positive assortative mating produces the greatest aggregate output over all marriages.[29]

Positive assortative mating has been reported in a variety of traits, for both humans and animals. A study on Swedish marriage data indicates positive assortative mating within both status and wealth (Almenberg & Dreber Unpublished manuscript).[30]

In the case of mixed matches between wealthy individuals and individuals with high status, however, the assortative mating is between traits rather than within a trait: individuals with high wealth but low status sorting with individuals with low wealth but high status. To the best of our knowledge, there have been no

[29] A proof is given in Becker (1991, p. 130). Note that the model is frictionless, in the sense that the optimal matching is assumed to come about of itself, without any reference to how the process of sorting actually takes place.

[30] There is a large literature on positive assortative mating as well as mate preferences in general. See, e.g., the references in Almenberg and Dreber (2009).

previous empirical economic examinations of assortative mating between status and wealth in the marriage market.

2.3 Status and Marriage

Economic theory blending the themes of status and marriage is scarce; these areas have typically been examined separately. A notable exception is Mailath and Postlewaite ((Mailath & Postlewaite 2006), henceforth M&P), who introduce the notion of a "social asset", being an asset that derives some or all of its value from social institutions. They distinguish between the fundamental and intrinsic values of an asset. A status marker that has no fundamental value may still have intrinsic value if it raises expected future income.

While typically non-transferable within a generation, M&P suggest that certain hereditary traits might have such instrumental value because parents typically care about not only their own consumption but also the consumption of their offspring: while hereditary traits cannot be traded contemporaneously, individuals who don't possess the trait can mate with individuals who do, in the hope that their offspring will inherit it.

The value of hereditary social assets may in part be due to the difficulty of insuring future generations against consumption risk: while any generation may squander a family's economic resources, the subsequent generations can still be endowed with a single asset that cannot be relinquished, and yet raises their expected consumption – namely, a trait that bestows status. In other words, each generation of a lineage can extract the flow value of the asset, but cannot extract the capitalized present value of future flows.

The valuation of such social assets may be self-fulfilling. If everybody else attaches value to an asset, it may become covetable also for individuals to whom it has no intrinsic value. Agents in the M&P model differ in terms of income (which is either high or low) and a binary trait. Income is assumed to be non-storable, so that parents cannot transfer consumption to their offspring. If individuals in possession of the trait are *ceteris paribus* more desirable partners, they will have a greater chance of marrying "up" in wealth. In this case, acquiring the trait through marriage becomes a means for the parents to insure against some of the consumption risk of their offspring. In other words, the best response of an individual in a society where others seek to marry individuals with the coveted trait may be to also seek to marry individuals with that trait, thereby raising the chances of their offspring having the trait and thereby higher expected income. Hence, in equilibrium the desirability of the trait can be self-fulfilling.[31]

The particular characteristics of the attribute are irrelevant: "Any heritable attribute might serve as a social asset in this way" (Mailath and Postlewaite 2006, p. 1059). Although M&P do not mention hereditary nobility, this institution fits the prescribed mechanism well. It is widely accepted that broad measures of ability such as IQ are mean-reverting. Noble titles were typically awarded in reward for distinguished service to the monarch. Such services often also resulted in pecuniary rewards, such as land grants. Family fortunes, however, can be lost in the course of a single generation, whereas hereditary nobility is inalienable: it cannot be sold since it cannot be transferred. For an individual with high ability and high income, nobility may have offered a means to insure against lower ability in a subsequent generation, and the associated risk of an inferior economic outcome for the individual's offspring.

3. MARRIAGE DATA

To shed more light on the role of nobility in marriage markets, we use a repeated cross-section of all marriages in Sweden during 1985, 1990, 1995, 2000 and 2004, in total 195,405 marriages.[32] We are interested in the individual probability of marrying up in wealth, hence each spouse is treated as a separate observation, giving us a sample of 380,810 observations. The data are drawn from the Total Population Register, contain every registered marriage during the years in question, and were compiled by Statistics Sweden on our behalf. The data contain information on a number of characteristics of bride and groom, including age, income, net wealth and level of education, all measured *at the time of marriage*. The data set also contains a dummy variable that takes the value 1 if an individual's surname denotes nobility, and 0 otherwise. A set of names belonging to the remaining families of the nobility was provided by the House of Nobility in Stockholm and used to generate this indicator. In the data set, 1,782 individuals belong to the nobility according to this indicator, equivalent to a bit less than 0.5 percent of the sample.[33]

[31] The offspring have higher expected income for two reasons: income may be correlated with the trait, and possession of the trait raises the likelihood of marrying a high income individual who in turns wants to insure the consumption risk of his/her offspring. The first mechanism is not a necessary requirement.

[32] At the time of writing, the data for 2005 was not yet available, so we chose the closest available data.

[33] This is slightly larger than the proportion of nobility in the general population (about 0.3%). This could be caused by nobility having an above average propensity to marry. Bearing this in

The control variables are defined in terms of brackets. In part this reflects the requirement from Statistics Sweden to protect individual integrity, given the small number of nobility in our sample. There are five (annual) income categories: [0–121,999], [122,000–199,999], [200,000–299,999], [300,000–499,999], and [500,000–].[34] Age is in the following brackets: (–24], [25–29], [30–34], [35–39], [40–44], [45–54], or [55–). The data on education places each individual in one of four categories, corresponding to pre-high school, high school, less than three years of tertiary education, and more than three years of tertiary education. Individual wealth belongs to one of four categories: [0–199,999], [200,000–499,999], [500,000–1,499,999], and [1,500,000–]. There is a high concentration of individuals in the lowest wealth bracket.[35] For each of these covariates, we construct a set of dummy variables corresponding to the aforementioned categories. In the regressions, the lowest bracket is the baseline for each categorical variable.

The wealth tax that was effective in Sweden until 2007 provided strong incentives for tax avoidance. Assets not taxed at all or entered in tax returns at levels below market value included real estate, land holdings, art and antiques, and shares of small-cap firms on the Stockholm stock exchange (not on the A-list). Given that there have been numerous ways of reducing taxable wealth in Sweden, it is unlikely that these figures show the individuals' full wealth. This reduces the efficiency of our estimator. In addition, it is a potential source of unobserved heterogeneity in the sample. Let W be the true wealth, and $(1-a)W$ the observed wealth of individual i, with $0 < a < 1$. If a is positively correlated with belonging to the nobility, our estimate of the nobility premium will be biased upwards. This could make what might in fact be positive assortative mating look like hypergamy. Note that even if a is correlated with nobility, our estimates of the difference in the nobility coefficient between male and female nobility will not be biased unless the correlation itself differs systematically between the sexes. We discuss unobserved heterogeneity more extensively in the next section.

4. HYPOTHESIS TESTING

4.1 From Marrying "In" to Marrying "Up"

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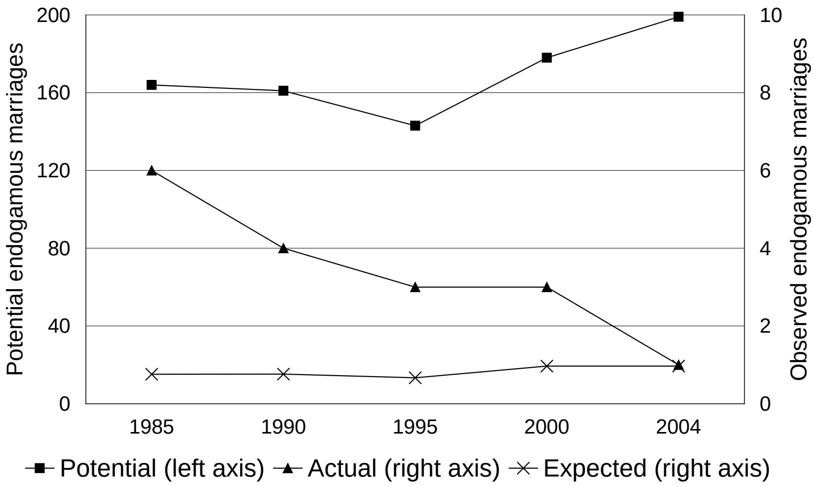
mind, we can only make inferences regarding the individuals that actually marry. It could also be caused by sampling error, due to some noble names not being distinct. In this case our estimates will be biased downward, thus underestimating the actual nobility premium.

[34] All amounts reported are nominal and measured in SEK. 1 SEK = approx. 0.1 USD, adjusted for purchasing power.

[35] Summary statistics can be sent to the reader upon request.

Traditionally, nobility were expected to marry within their own ranks. The marriage market data indicate that this is changing. Endogamy (within-group marriage) still occurs: the odds of a spouse belonging to the nobility are more than twice as high if an individual also belongs to the nobility (logit regression, $\beta_{nobility}$: 1.20; *p*-value < 0.001). The coefficient on the nobility dummy is large compared to the coefficients on age, income or wealth.[36] Yet, the tradition of endogamous marriage seems to be coming to an end. The great majority (98%) of the nobility in our sample are not married to other nobility, and the number of marriages in which both spouses belong to the nobility declines monotonically over time. *Figure 1*, below, shows the actual number of endogamous marriages among Swedish nobility observed in our sample, by year. This is plotted against the potential number of such marriages, defined (somewhat arbitrarily) as the minimum of male/female nobility getting married in that year. The third series shows the expected number of such marriages, if nobility were randomly assigned to males and females in our sample. There are two salient features of *Figure 1*. First, the frequency of endogamous marriage has been steadily declining, despite a more or less constant number of nobility in the marriage market. Second, the rate of endogamous marriage has been converging toward, and recently reached, the level that we would expect to observe with random matching.

Figure 1
Endogamous Marriages among Swedish Nobility, 1985-2004



In other words, endogamous marriage within the nobility, once considered the norm, has become an unusual occurrence.[37] For the most recent observations in

[36] For the interested reader, a full table of the regression results can be provided upon request.
[37] By contrast, (Banerjee et al. Unpublished manuscript) report that within-caste marriage is still prevalent in India.

our data, such marriages occur at a rate no greater than what we would observe under random matching. One interpretation of this pattern is that nobility, in response to modernizing reforms that curtail their economic influence, turn to exogamy as a dominant strategy for securing access to resources. This process may have gone on for some time: for example, strategic marriages between British nobility, rich in symbolic capital but cash poor, with the daughters of American industrialists in the late 19th and early 20th century have been documented by historians (Cannadine 1990).

In Sweden, the waning influence of the nobility in the 20th century was reflected in a marked decline in their statistical overrepresentation on company boards, in the foreign service, and other prestigious positions (Rundblad 1999). In 1968, individuals belonging to the nobility constituted 12 percent of all board members of the 50 largest companies on the Stockholm stock exchange. By 1998, this had declined to 4 percent.[38] In the foreign service, nobility constituted 26 percent of all ambassadors and consul generals in 1968. This had declined to 8 percent by 1998 (Rundblad 1999). When the formal privileges of nobility were curtailed, marrying up in wealth may have gained importance as a means of securing access to material resources.[39]

4.2 Regression Analysis: Is There a Nobility Premium?

Having noted that nobility are not marrying within their group to any great extent, we now turn our attention to whether they are marrying up in wealth. According to our hypothesis, wealthy individuals will covet status markers in general and hereditary, inalienable status marker in particular, resulting in a higher probability of marrying up in wealth for individuals belonging to the nobility. To test this hypothesis, we construct an indicator variable that takes on the value 1 if individual i marries into a higher wealth bracket, and 0 otherwise. To examine the robustness of our results, we test a number of different specifications of this indicator, including the transition probabilities between specific wealth brackets. Our results are broadly robust to such modifications.

We use the logistic binary response model (logit regression) to estimate the probability of an individual marrying a spouse in a higher wealth bracket. The

[38] As measured by turnover (Rundblad 1999).

[39] Note that from a long-term perspective, this loss of privileges coincided with the emergence of the Swedish welfare state and a reduction in income inequality. Frey (2006) argues that awards should play a more important role as status markers in countries with low income dispersion and less pervasive market ideology. To the extent that this analysis carries over to nobility, an inherited award, these developments could in fact have raised the value of nobility in the marriage market at the same time as nobility were losing their explicit privileges.

logistic functional form generates estimates that are bounded on the unit interval, and hence has an intuitive appeal when the dependent variable is a binary outcome.

We regress a dummy variable that indicates marrying up on an individual's age, education, income, wealth, and sex, as well as whether the individual belongs to the nobility.[40] We have no reason to believe that the parameters of the true model are the same for both sexes. For this reason, we run separate regressions for women and men.[41] Since we are also interested in how the nobility coefficient differs between the sexes, we also run a joint regression where we allow all coefficients to differ between the sexes. We include a dummy variable indicating whether the individual is male, allowing for different baseline probabilities for men and women, and interaction terms between the male dummy and the independent variables, including the nobility dummy, thus allowing for the slope coefficients to differ between the sexes.

The joint regression offers a statistical measure of how the nobility coefficient differs between the sexes. A Wald test rejects that these interaction terms are jointly insignificant (p-value < 0.0001). In each regression, we also include a full set of controls for the spouse, to make sure that we are not confounding an increased probability of marrying up in wealth with an increased probability of marrying somebody with higher age, income or education. Note that in order to run a joint regression, we rearrange the observations so that each individual appears twice, once as individual i and once as a spouse. This allows us to estimate the probability on the whole population of individuals in the sample. For the regression on the joint sample, where we allow the coefficients to differ between the sexes, we can write our regression specification as a logistic probability model of the form

$$P\left(Y_{ij} = 1 \middle| \mathbf{X}_{\mathrm{ij}}\right) = 1 \,/\, \left(1 + e^{-\left(\alpha_j + \mathbf{X}_{ij} \beta_j + \delta_j \text{Nobility }_i\right)}\right) \tag{1}$$

where $P\left(Y_{ij} = 1 \middle| \mathbf{X}_{\mathrm{ij}}\right)$ denotes the probability of marrying up for an individual i of sex j, conditional on the covariates. Nobility is a dummy variable that takes on the value 1 if individual i belongs to the nobility, and $\mathbf{X}_{\mathrm{i}}$ is the vector of controls mentioned above. The subscript j denotes gender. *Table 1* summarizes the results from the regressions, for both sexes separately (columns 1 and 2), and for the joint sample (column 3).

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[40] Since individuals in the highest wealth bracket cannot marry up, we exclude these observations from the analysis. In our main regression, we do not control for the spouse belonging to the nobility. Our results are robust to the inclusion of this control. They are also robust to omitting all spouse controls.

[41] Our approach is similar in spirit to that of (Elmslie & Tebaldi 2008) who examine socioeconomic determinants of infidelity.

Table 1

Dependent Variable: Marrying "Up" in Wealth

	Women	Men	All
	(1)	(2)	(3)
Nobility	0.390	0.434	0.382
	(0.021)**	(0.031)**	(0.024)**
Male*Nobility			0.055
			-0.834
Additional Controls	Yes	Yes	Yes
Interaction terms (*male)	No	No	Yes
Male			-0.473
			(0.000)***
Constant	-5.129	-5.517	-4.919
	(0.000)***	(0.000)***	(0.000)***
N	171187	170464	341651
R^2/Pseudo-R^2	0.141	0.141	0.146

Robust standard errors. *p* -values in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

The coefficient for nobility is positive and statistically significant in all specifications. Columns 1 and 2 show that both male and female nobility have higher probabilities of marrying up in wealth, when controlling for the available covariates. The coefficient is larger for noble men than for noble women. Column 3 shows the same thing, but the difference is not statistically significant. We rely on the specification in column (3) of *Table 1* as our main model, and interpret our results below.

The observed nobility premium is sizeable. The wealth distribution in our sample is heavily concentrated in the lowest bracket. When an individual marries up, his/her spouse by definition marries down. Hence, the largest potential number of marriages in which one individual marries up in wealth equals the number of individuals in the second, third and fourth wealth brackets, about 3.2% of the sample. As a result, marrying up in wealth is a rare event, achieved by only 2.6% of the individuals in our sample. For nobility, however, this frequency is 4.4%. In essence, our regressions show is that including a number of relevant controls does not diminish this nobility premium. In the main regression (*Table 1*, column 3), the estimated nobility premium is an almost 40 percent increase in the odds of marrying into a higher wealth bracket.

While the interaction term between nobility and being male has the expected (positive) sign in the logit regression in column 3, it is not statistically significant.

This implies that we cannot reject that the increase in probability is of the same magnitude for noble men and noble women. Thus, we do not find conclusive support for our auxiliary hypothesis of a gender gap in the nobility premium.[42]

Nobility might be correlated with variables that we are unable to control for in the sample, for example human and social capital, or even physical appearance.[43] If such unobserved heterogeneity is a direct consequence of nobility, this does not undermine the validity of our findings. It is important to recognize, however, that there might be other unobserved variables that could arguably affect our results. This is a further reason for interpreting our results with some caution. Nobility are slightly over-represented among individuals that marry, implying that there might be some selection bias. Moreover, if the fraction of an individual's wealth that goes unreported is positively correlated with belonging to the nobility, then our estimates will be biased upward. Nobility are "to the right" of the general sample in terms of the wealth distribution. Nobility may have wealthier parents than other individuals in the same wealth bracket. An individual marrying a member of the nobility with no wealth could be expecting future wealth through inheritance. Another possible omitted variable would be that past wealth is positively correlated with residing in affluent neighborhoods, and residing in affluent neighborhoods may be positively correlated with the probability of marrying "up".

A more sophisticated modeling approach to the marriage market would add additional complexity to the interpretation of our results. Hypothetically, nobility could be more prevalent in marriage markets in which population densities, the fraction of singles, and sex ratios among singles differ from the population average. In a search model of the marriage market, these factors would be expected to influence the reservation price at which a match is made (Drewianka 2003). Controlling for such factors is beyond the scope of our data set, but would constitute an interesting avenue for further research.

While each of these concerns is valid, they affect only the interpretation of our findings, and not their implications. Regardless of whether nobility marry up in wealth because their nobility is a covetable status marker or because they live in affluent neighborhoods etc., the consequence of this hypergamy is that economic resources are channeled toward nobility at a time when they have relinquished all explicit economic and political privileges. To the extent that access to resources is linked to reproductive success, this may have considerable implications for the

[42] We also estimate a linear (OLS) model using the same specification. With this functional form, the interaction term between male sex and nobility has the wrong sign, and is still not statistically significant. Because the R^2 of the linear model is considerably lower than for the logistic model, we focus mainly on the latter. Estimates for the linear model can be provided upon request.

[43] For an economic perspective on social capital, see, e.g., (Sabatini 2008)

longevity of nobility as an institution and for the intergenerational transmission of inequality.

4.3 Robustness Checks

We conduct a number of robustness checks to test the validity of our results. Our conclusion, based on these checks, is that our results are robust. A non-technical summary of the robustness checks follows below.

Our first robustness check consists of examining whether our main finding, the nobility premium, is consistent with alternative measures of hypergamy. The measure we use for our main regression, reported in *Table 1* above, is the probability of marrying an individual in a higher wealth category. Let x_i , y_i denote the wealth bracket of individual i and individual i's spouse. Our main model corresponds to estimating the probability of $y_i > x_i$, conditional on the covariates. To check the robustness of our findings, we use the same model specification, except that we use three other measures of hypergamy: (1) $x_i = 1, y_i \geq 2$; (2) $x_i \leq 2$, $y_i > 2$; and (3) $x_i = 1, y_i = 4$. We find evidence of a nobility premium of similar magnitude in all the aforementioned cases, suggesting that our results are not particularly sensitive to the choice of hypergamy measure. Coefficients and p-values for the nobility dummy are shown in *Table 2*, below.

Table 2
Robustness Checks

	Nobility dummy	
Measure of hypergamy	Coefficient	p-value
$x_i = 1, y_i > 1$	0.499	(0.003)***
$x_i < 3, y_i > 2$	0.400	(0.077)*
$x_i = 1, y_i = 4$	0.862	(0.003)***

Robust standard errors. p-values in parentheses
*significant at 10%; **significant at 5%; ***significant at 1%

A second purpose of these checks is to examine whether our results are driven by differences in the distribution of nobility and non-nobility within wealth brackets. The wealth distributions of the nobility and of the general sample are different, with the probability mass of the former being “to the right” of the latter, in the sense of stochastic first order dominance. Given the high level of aggregation – only four wealth brackets – differences in the distribution within each bracket might influence our results. If, for example, the average wealth of nobility in the lowest wealth bracket is higher (lower) than average wealth of non-nobility in the same bracket, our estimate for this group would be biased upward (downward). As an additional precaution, we also estimate the probability of marrying "down". We run a regression similar to the one above, except that the dependent variable is a dummy variable indicating whether an individual from the second, third or fourth wealth bracket marries an individual in a lower wealth bracket, $x_i > y_i$.[44] If nobility in the higher wealth brackets on average have higher wealth than other individuals within that bracket, then they should be less likely to marry down. We find no evidence of such an effect (nobility dummy p-value < 0.971). We conclude that our results are not likely to be driven by differences in the distribution of nobility and non-nobility within wealth brackets.

5. CONCLUSION

We have attempted to fuse the research on status with that on mating patterns, by examining the relative performance of hereditary nobility, a proxy for status, in the marriage market. In Sweden, nobility no longer enjoy formal privileges, yet anecdotal evidence suggests that nobility remains coveted. Since nobility is not traded in open markets, we study the marriage market as a conduit for such transactions.

We find that nobility enjoy a higher probability of marrying up in wealth. Because our sample is heavily concentrated in the lowest wealth bracket, we observe few individuals marrying up in wealth. For the general sample, the rate is 2.6%. For the subsample belonging to the nobility, however, this rate is 4.4%. We have shown that this apparent nobility premium is robust to controlling for a number of relevant variables.

The data also indicate a gender difference, with males, for whom nobility is heriditary, attaining a higher premium. The gender difference, however, is not statistically significant. Taken together, these two results could be explained in several ways. To suggest a few: (1) There is a nobility premium, and it is higher for males. The sample contains enough individuals belonging to the nobility to detect the premium, but not enough to identify the gender difference. (2) There is a nobility premium, and it is higher for males. Other gender differences in mate preferences obscure the gender difference in the nobility premium. (3) There is a nobility premium, because individuals care about their own status, but no gender

[44] Note that this regression is, in practice, not perfectly symmetrical with a regression looking at the probability of marrying up. The former omits individuals in the lowest wealth bracket, who by definition can't marry down. The latter omits individuals in the highest wealth bracket, who by definition can't marry up.

difference, because individuals do not care about their children's status.[45] (4) There is no nobility premium. The observed effect is driven by unobserved heterogeneity.

Our data does not enable us to discern which, if any, of these alternative explanations is the correct one. Hypothesis testing on our sample of observational data rejects the null hypothesis that nobility do not have better chances of marrying up in wealth. The data has clear limitations, and we are not able to rule out concerns about unobserved heterogeneity – as is always the case with observational data. We wish to emphasize that the results presented here are a first step toward a better understanding of the nobility premium, and we encourage other researchers to shed more light on this topic. We will conclude by discussing some possible implications of a nobility premium.

Who marries whom influences future generations to the extent that the characteristics of the parents are passed on to their children, through their genes as well as a shared environment. Who marries whom is therefore an indicator of the distribution of a wide range of characteristics of successive generations. In a similar manner, the distribution of culturally determined status markers in the population may have important effects on economic outcomes.

In an era when their formal privileges have been curtailed, a marriage premium for nobility suggests a positive valuation of the status marker itself. If the symbolic capital of nobility continues to attract a premium in the marriage market, this provides an additional mechanism that reinforces the persistence of social stratification and inequality. Moreover, if status and consumption of other goods are complementary as another study suggests (Becker et al. 2005), and if status markers are becoming relatively more scarce, the nobility premium might well be increasing over time.[46]

If access to material resources is correlated with greater reproductive success, a marriage market premium would imply that nobility may persist for a long time, even if no new nobility is created. Historically, male nobility, and rich men in general, have reproduced to a greater extent than other men (Clark 2007). This is not surprising given that these men tended to be in the upper strata of wealth and status, and had privileges held by neither commoners nor noble women. Wealth and status have both been found to correlate positively with male reproductive

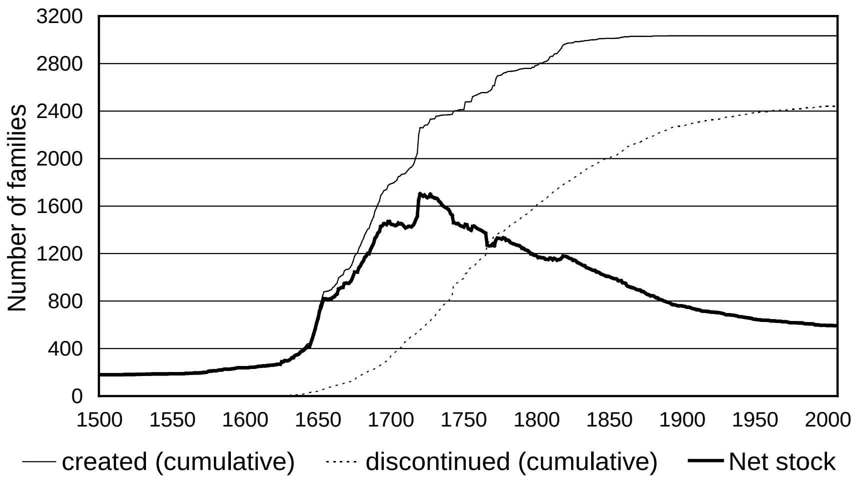
[45] This would contradict the assumptions of the model in Mailath and Postlewaite (2006). It would also contradict the large literature on bequest motives.

[46] Becker et al. (2005) show how the price of status relative to other consumption goods increases when status markers become relatively more scarce. In a similar vein, Frey (2006) argues that the value of an award is increasing in its scarcity. It is plausible that this applies also to inherited awards.

success among other groups, such as 19th Century Mormons (Mealy 1985) and the Ifaluk in Micronesia (Turke & Betzig 1985).

When nobility is only passed on through male offspring, the perpetuation of nobility requires a continued male lineage. We merged data in Fahlbeck (Fahlbeck 1898) with 20th Century records from the House of Nobility in order to trace the evolution of the stock of noble families over time.[47] Note that the number of families is the observed quantity, and has not been corrected for population size.[48] *Figure 2* shows the evolution of the stock of noble families since the year 1500. The net stock (thick solid line) is the difference between the number of families that have been elevated to nobility (thin solid line) and the number of noble families whose male lineages have been discontinued (dotted line).

Figure 2
The Evolution of the Stock of Noble Families Since the Year 1500



A rapid decline in the creation rate has caused the stock of nobility to decline monotonically in the last 200 years (i.e., in peacetime). The recent decline is well described by a simple model of exponential decline. When fitting such a model to

[47] These records are as yet incomplete: while it is generally known if a male lineage has been discontinued, it is not always known in which year this happened. In the cases where the decade, but not exact year, was known, we used the middle year of that decade. In the cases where not even the decade was known, the discontinuation year was imputed using linear regression. The discontinuation year was imputed using information on year of creation, monarch at time of creation, and the occupation of the first member of the noble lineage. Approximately 10 percent of all discontinuation dates were imputed in this manner.

[48] The analysis is made slightly more complicated by the fact that the dataset includes families that were raised from the lower ranks of nobility to the higher, titled ranks. This applies to about 20 percent of the sample. The branch that was elevated to a higher rank is counted in the data as the creation of a new noble family, which overlooks the fact that it stems from a male lineage that is already noble. Excluding this subset, however, has negligible effects on the general picture.

this data, we get a predicted half-life of about 100 years for the stock of nobility.[49] There are currently almost 600 remaining noble families. If the stock continues to decline at this rate, there will remain about 300 families by the year 2100, 150 families by the year 2200, and so forth. In sum, nobility as an institution appears to have considerable longevity, despite no longer enjoying economic or political privileges. If this simple model above comes close to predicting future developments, we ought to conclude that simply ceasing to create new noble families is not a very effective way of terminating the institution of nobility.[50]

Hereditary nobility is an anachronism. Our analysis can be extended, however, to other hereditary status markers which may perpetuate in modern times. For example, several Ivy League universities have adopted a so called "legacy policy", whereby the probability of acceptance is higher, *ceteris paribus*, if a parent has attended the same university (Karabel 2005). To the extent that an Ivy League education is a positional good, alumni status might come to play a similar role in marriage markets in the future. We encourage future research in this area.

In sum, status affects economic outcomes, and is positively assorted with wealth in the marriage market. Given the hereditary nature of nobility, this mating pattern has consequences for the transmission of inequality. Not only does wealth beget wealth in the marriage market, but an indicator of past wealth does so, too. We end our discussion by noting that the marriage of wealth and status is an old and familiar theme. Well known representations in popular culture include Hogarth's *Marriage à la Mode*, a series of 19th century engravings featuring a cash poor aristocrat, Lord Squanderfield, who marries off his son to the daughter of a merchant. In di Lampedusa's (1966) novel *The Leopard*, Don Fabrizio, an ageing Sicilian prince, reluctantly marries off his orphaned nephew to the daughter of a local businessman with new-found wealth but no pedigree (di Lampedusa 1966). In a revealing episode, Don Fabrizio is told that the prospective bride's grandfather

[49] Let $S(t)$ denote the stock of noble families at time t, normalized by population size. From a regression of log(S) on the time interval since 1900, we get a time coefficient of -0.0079 (OLS with robust standard errors, p-value < 0.001, $R^2 = 0.986$). Entering this estimate into the model of exponential decline we get an expression for the evolution of the stock of nobility over time:

$$S(t)=S_0 e^{-0.0079(t-1900)}$$

[50] This reasoning assumes no frequency-dependent advantage. If, for example, the marriage market valuation of nobility is an increasing function of the scarcity of nobility, a frequency-dependent nobility premium might arise. This would imply far greater longevity for nobility than is predicted by our exponential model. Exploring the ramifications of this more fully would constitute an exciting avenue for future research. It should also be noted that since no new noble lineages are created, the institution is likely to eventually cease to exist, although this might take a very long time. In stochastic models of population dynamics, lineages are typically either eliminated or go to fixation (so that the entire population stems from the same lineage). In the case of nobility, both outcomes would make the institution redundant.

Peppe was known by an unflattering nickname: "Peppe 'Mmerda". The prince is taken aback by this information, but remains determined to press ahead with matters. *Non olet*, he reminds himself, *non olet*.[51]

[51] (Latin) *Pecunia non olet*: money does not smell.

Paper 6

When Does the Price Affect the Taste? Results from a Wine Experiment

Joint work with Johan Almenberg[52]

ABSTRACT

We designed an experiment that examines how knowledge about the price of a good, and the time at which the information is received, affects how the good is experienced. The good in question was wine, and the price was either high or low. Our results suggest that hosts offering wine to guests can safely reveal the price: much is gained if the wine is expensive, and little is lost if it is cheap. Disclosing the high price before tasting the wine produces considerably higher ratings, although only from women. Disclosing the low price, by contrast, does not result in lower ratings. Our finding indicates that price not only serves to clear markets, it also serves as a marketing tool; it influences expectations that in turn shape a consumer's experience. In addition, our results suggest that men and women respond differently to attribute information.

1. INTRODUCTION

Much economic analysis assumes that price simply reflects market structure, but price can also be a marketing tool, for example if the price tag itself affects how a good is perceived (see, e.g., (Cialdini 1998)). Textbook illustrations of supply and demand typically feature downward sloping demand curves. For most goods this is a highly plausible assumption. Price may have a positive effect on demand, however, when the good in question is used for the purpose of costly signaling. In the case of positional goods (Veblen goods), the purpose is to signal affluence and thereby assert high status (see, e.g., (Frank 1985; McAdams 1992; Frank 1999)). A closely related example on the supply side is when increased monetary incentives

[52] We thank Emma von Essen, Magnus Johannesson and Eva Ranehill for great comments on the manuscript, and Thomas Pfeiffer, David G. Rand and Nils Wernerfelt for great assistance during the wine tastings. Johan Almenberg thanks the Jacob Wallenberg Foundation and the Torsten and Ragnar Söderberg Foundations for financial support, and Johan Almenberg and Anna Dreber thank the Jan Wallander and Tom Hedelius Foundation for financial support.

crowd out intrinsic motivation for providing a service (Gneezy & Rustichini 2000a; Gneezy & Rustichini 2000b; Mellström & Johannesson 2008). In this case the purpose may be to signal altruism and thereby achieve social esteem (Bénabou & Tirole 2006; Ellingsen & Johannesson 2008). In both cases the price tag carries a semantic component, in the sense that it affects the signaling value of the commodity in question.

In practice, it can be hard to distinguish the signaling value of a high price from the tendency to associate high price with high quality. Consumers have been found to expect a positive correlation between price and quality (Rao & Monroe 1989). Consistent with this expectation a meta-analysis has found positive correlations between price and quality ratings for most of the 1,200 product markets surveyed, but also that the range of these correlations is large, and even negative for some markets (Tellis & Wernerfelt 1987). Consumers' perceptions of objective price-quality relationships have been found to be only moderately accurate (Lichtenstein & Burton 1989), and the price-quality heuristic can be misleading, for example when goods of low quality are priced high (Cialdini 1998).

In this paper, we address one particular good – wine – to shed some more light on the relationship between the price of a wine and the individual enjoyment of the wine. Specifically, we explore if, and how, information about the price of a wine affects the experience of tasting the wine.

Attribute information, such as the price or the ingredients of the good, has a more powerful effect on the perception of quality when the experience of the good is ambiguous (Hoch & Ha 1986). Tasting wine is a relatively ambiguous experience for many consumers. Objective measures of wine quality are not easily defined, and consumer tastes with regard to wine are highly heterogeneous (Amerine & Roessler 1976; Lecocq & Visser 2006). Wine judges display low within-subject correlations when unknowingly judging the same wine multiple times (Hodgson 2008).[53] Tasters are only marginally better than a random guess at distinguishing vintage years from non-vintage years from the same vineyard, or reserve bottlings from regular bottlings from the same vineyard and year, despite very large differences in price (Weil 2001, 2005).[54] And in a large sample of blind tastings, Goldstein et al. (2008) find that more expensive wines fail to get higher ratings.

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[53] In fact, only about 10% of the judges were able to replicate their score within a single medal group. Moreover, when the judges were consistent this usually happened for wines that they disliked. This study is particularly interesting given that another study has found a positive relationship between price and medal status such that awards can influence a winery's economic success (Lima 2006).

[54] In Weil (2005) subjects are to distinguish between a reserve bottling and a regular bottling, from the same producer and year. Among those who can distinguish between these two bottlings, only half prefer the reserve, whereas the wines differ in price by an order of magnitude.

Previous research indicates that price information may be an important determinant of the experienced pleasantness of a wine (Brochet 2001; Plassmann et al. 2008). Using functional magnetic resonance imaging (fMRI), Plassmann et al. (2008) conduct a within-subject study with 20 participants. Each subject tasted three wines multiple times, but were not always told which wine they were tasting. Subjects believed they were tasting five different wines that differed greatly in price. Two of these wines were in fact duplicates of two of the other wines, but labeled with a different price tag. For the tasting observations where the subjects were unaware of the price, ratings did not differ between two samples of the same wine. By contrast, when the supposed price was disclosed, the price level was found to correlate positively with experienced pleasantness, measured through both subjective reports and fMRI scans.[55] This research highlights the potential role of marketing in shaping how we experience the goods that we consume.

Plassmann et al. (2008) do not ascertain whether expectations constitute the mechanism whereby price affects the tasting experience. We extend their analysis by using an alternative methodology from consumer research. Our aim is to shed more light on the price effect, and, in particular, to better understand the mechanism through which price information exerts influence on the tasting experience. Unlike in Plassmann et al. (2008), our setup relies on between-subject comparisons, and does not involve deception.[56]

Our approach combines an information treatment with a timing treatment. By varying both the provision and the type of extrinsic information, as well as the timing of this information relative to the first-hand experience of the wine, our experiment sheds light on how consumers use extrinsic information about the product in forming an opinion about it. A blind setting, in which the extrinsic information is not disclosed, is compared to a setting in which the information is disclosed before tasting, as well as a setting in which the information is disclosed after tasting.

A similar setup has been used in consumer research, applied to clothing, paper towels and ground beef (Hoch & Ha 1986; Levin & Gaeth 1988). It has recently been applied to beer by Lee et al. (2006) who look at how knowing about a "secret ingredient" (vinegar added by the experimenter) affects experienced pleasantness (Lee et al. 2006). All three studies find that extrinsic information provided prior to

[55] Subjects' brains were scanned while subjects tasted the wine. The results show that increasing the price of the wine increases blood-oxygen-level dependent activity in an area thought to encode for experienced pleasantness (the medial orbitofrontal cortex).

[56] It is not self-evident that labeling a $90 wine as a $10 wine captures the appropriate price effect, which would be the difference in subjective well-being experienced when tasting a wine without knowing the true price relative to tasting this wine when aware of the price.

first-hand experience with the good in question has a significant effect of how the good is experienced, whereas extrinsic information provided after the experience does not.

We replace the beer in Lee et al. (2006) with wine, and replace information about a secret ingredient with information about the wine's retail price per bottle ($40 or $5). Vinegar in beer is likely to be bad news about the beverage to the minds of most beer consumers. By contrast, our experiment was designed to allow for positive information (the wine is expensive) as well as negative information (the wine is cheap).[57] Thus, we focus on price as an attribute, an important element in marketing (Cialdini 1998).

The first purpose of our study is to gage the magnitude of both the positive and the negative expectational effect. We hypothesize that individuals will assign a higher rating to the wine when they know its high price, relative to those tasting it without knowing the price. We assume that many consumers expect a $40 wine to be a highly pleasant experience. We hypothesize that individuals will assign a lower rating to the wine if they know the price and consider it to be cheap. We assume that many consumers will not expect a $5 wine to be a very positive experience.

Second, we expect the timing of the price information to make a difference. Hoch and Ha (1986), Levin and Gaeth (1988), and Lee et al. (2006) find that information has a significant effect only when disclosed prior to first-hand experience of the good in question. On the basis of this we expect the information about price to have a larger effect, relative to the blind condition, in the before condition than in the after condition. In other words, we expect individuals to give higher ratings to the expensive wine when they know about the high price before tasting, but not necessarily when finding out about the price after tasting, and similarly with the cheap wine we expect individuals to give lower ratings when they know about the price before tasting.

Third, we test whether there is a gender difference in how the price information matters. The possibility of a gender difference was not intended as the focus of our study. It is highly plausible, however, that concerns about identity and social image form part of a price effect. Gender differences in behavior are commonplace in the experimental economics literature in general (Croson & Gneezy 2008) and a number of studies find that men and women respond differently to treatments designed to trigger social concerns (e.g., (Griskevicius et al. 2007; Mellström & Johannesson 2008; Rand et al. 2009; von Essen & Ranehill 2009)). Given this, we have no reason to expect the effect of price on experienced

[57] Whether the prices are perceived in this way depends partly on the subjects' spending habits. We address this issue later in the paper.

pleasantness to be the same for men and women. Plassmann et al. (2008) do not control for such gender effects, and we are not aware of any test of gender differences in how the timing of the (price) information affects experienced pleasantness.

We find that an expensive wine gets considerably higher ratings when tasters are informed about the high price before tasting, relative to tasting "blind" – but only from female tasters. By contrast, women that taste the wine before being told the price do not assign significantly higher ratings, suggesting that once they form a first-hand opinion the attribute information has little effect. For men there is no significant difference between any of the three conditions. A possible interpretation of this discrepancy is that men and women respond differently to attribute information, with men being less sensitive to such cues. Alternatively, this might point to differences in how men and women relate to wine, or status, or both.

For the tasters that sampled the cheap wine, being informed about the price tag did not produce any noticeable changes in average ratings. This could point to an asymmetry between how positive and negative information shape perceptions of quality. A more likely explanation is that the bad news simply wasn't that bad: whereas the expensive wine was considerably more expensive than the tasters reported usually spending on wine, the cheap wine was simply in the lower range of typical spending. We elaborate on this later in the paper.

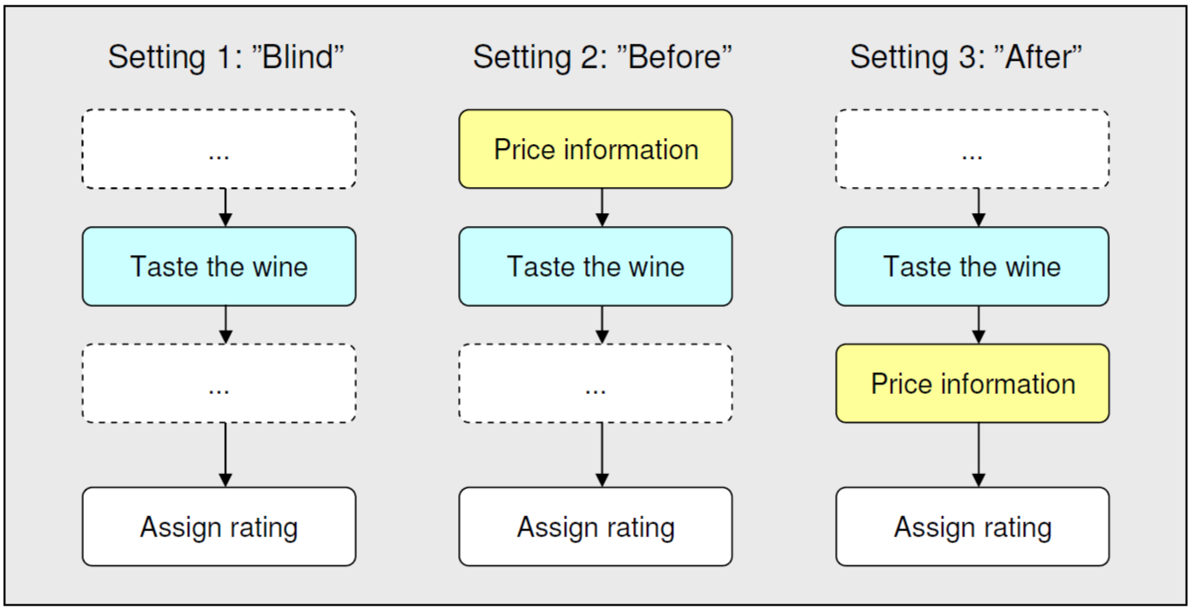
The outline of the paper is the following. We start by describing the setup of the experiment, then present our results, and finish the paper with a discussion.

2. SETUP

All subjects followed the same procedure, illustrated in Figure 1 below. First, they received some information about the experiment. Next, they tasted one of two wines. The wine was either expensive or cheap. Finally, they received a short questionnaire, at the beginning of which they were asked to rate the wine. There were three information settings. In the "blind" setting, the price was not mentioned in the experiment. In the "before" setting, the price was mentioned in the information about the experiment, prior to tasting the wine. In the "after" setting, the price was mentioned at the top of the questionnaire, after having tasted the wine but still before rating it. Subjects were allocated randomly to one of the three information settings and one of the two wines. In other words, we use a between-subject design.

Figure 1

Experimental setup



Apart from the price, subjects received the same information in all three settings. They were told that the wine came from Portugal, that it was made out of a blend of different grapes, that they were to receive a glass of wine that they were to taste and that they subsequently would be asked to rate the wine.[58] In the actual tasting of the wine, subjects were given wine glasses filled with a small quantity of the wine and then given a few minutes to taste the wine. Once the subjects had indicated that they were done tasting, they were asked to set aside the glass until the experiment was over. Next, they were asked to assign a rating, using a visual analogue scale ranging from "undrinkable" to "perfection", with "OK" as the midpoint. Aside from this the scale was not labeled. Subjects were asked to circle a point (a tick mark) anywhere on the axis. In the statistical analysis we convert this to a 100 point scale.

3. RESULTS

The study was conducted in Boston and Cambridge, Massachusetts, during the fall/winter semester of 2008-09. 135 individuals (40% women) tasted and rated

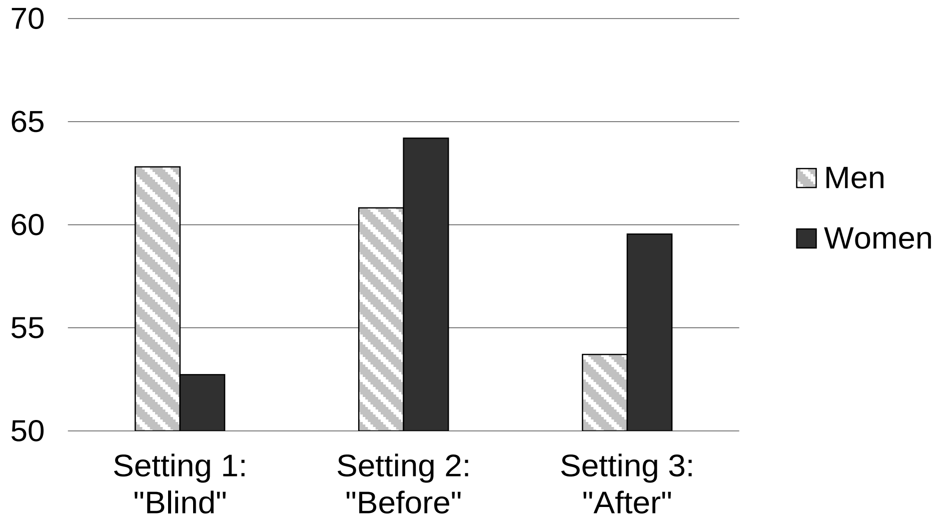
[58] Subjects in the same session were randomized to different treatments. Making sure everybody read something made subjects not realize there were different treatments. In addition, we did not want subjects to sense that we were exploring the effect of the price tag. Embedding the price information among other information about the wine made this less obvious.

a red wine with a retail price of $40, and 131 individuals (33% women) tasted and rated a red wine with a retail price of $5. The subjects consisted mainly of students and researchers at three universities. The average age was 29 (min: 21; max: 66).

3.1 The Expensive Wine

Across all experimental settings and subjects the average rating of the expensive wine was about 59 out of 100. Average ratings by setting and gender are shown below.

Figure 2
Average rating of the $40 wine, by gender and experimental setting.



The experimental data shows that the price can have a large effect on wine ratings, but this effect differs greatly between the sexes. Women, on average, assigned considerably higher ratings to the wine when they were informed about the $40 price tag before tasting. In terms of a 100 point scale, this effect implies that the rating increases by, on average, about 11.5 points. In terms of the visual analogue scale that subjects used for rating the wine, this effect represents about a quarter of the distance between “OK” and “perfection”. The effect is statistically significant at the 5% level, regardless of whether we run the regression separately for both sexes or jointly, incorporating a dummy for being female as well as interaction terms for being female and the two information treatments. In the joint regression, the interaction term is statistically significant, and a Wald test rejects that the sum of the coefficients on “before” and the interaction term “before x female" is equal to zero (p=0.024). Men, by contrast did not assign higher ratings to the wine when they were informed about the price before tasting it.

Table 1

Experimental results for the expensive wine

	All subjects	Men	Women
Information about the price:			
Before *tasting (and rating)*	-2.00	-2.00	11.48
	(0.643)	(0.642)	(0.028)**
After *tasting (but still prior to rating)*	-9.11	-9.11	6.83
	(0.088)*	(0.088)*	(0.216)
Gender			
Female	-10.09		
	(0.039)**		
Gender interactions			
Before x *Female* [1]	13.47		
	(0.044)**		
After x *Female*	15.93		
	(0.037)**		
Constant	62.81	62.81	52.72
	(0.000)***	(0.000)***	(0.000)***
Observations	135	81	54
R^2	0.058	0.044	0.083

Robust p-values in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%

[1)] Note: a Wald test rejects that *Before* + *Before* x *Female* = 0. Prob > F = 0.024.

Neither women nor men assigned higher ratings to the wine when they were informed about the price tag after tasting. There is a noticeable tendency for men to assign lower ratings to the wine when they are told about the price after tasting. This effect is marginally statistically significant (p=0.09). Ten subjects, however, reported having some form of wine training, and if we extend our regression analysis to control for this the coefficient becomes smaller for men and seizes to be even marginally statistically significant (coefficient size: -7.40 instead of -9.10, p=0.185). We do not present this extended framework as our main model, because the number of subjects reporting wine training was small.[59] Moreover, they were all men. Nonetheless, this indicates that the negative effect for men in the after condition is not robust.

In other words, extrinsic information arriving after the subject has had first-hand experience of the good does not alter the subject's opinion of the good's quality. This is consistent with previous studies using the same design: Hoch and

[59] Controlling for expertise is justified, however, since it has previously been found that experts rate wines differently from non-experts (Goldstein et al. 2008).

Ha (1986), Levin and Gaeth (1988), Lee et al. (2006) all find that information provided before experiencing the good has a significant effect on how the good is perceived, and that information provided afterwards does not.

3.2 The Cheap Wine

Across all experimental settings and subjects the average rating of the cheap wine was about 57. In the blind setting, the average rating was actually slightly higher for the 5$ wine than for the $40 wine (60.0 versus 58.5), in line with the finding in Goldstein et al. (2008) that most people do not prefer expensive wines, although this difference is not statistically significant.

For the cheap wine, we are unable to reject the null hypothesis that knowledge about the price has no effect on ratings, for either gender in any of the settings. Our data gives some indication of a corresponding negative effect of knowing about the low price of a cheap wine, but the absolute size of the effect is small and not statistically significant.

Table 2
Experimental results for the cheap wine

	All subjects	Men	Women
Information about the price:			
Before *tasting (and rating)*	-2.18	-4.74	1.15
	(0.66)	(0.37)	(0.87)
After *tasting (but still prior to rating)*	-7.13	-7.13	-3.08
	(0.19)	(0.19)	(0.72)
Gender			
Female	3.02		
	(0.67)		
Gender interactions			
Before × Female	-1.26		
	(0.86)		
After × Female	4.05		
	(0.69)		
Constant	58.98	58.98	62.00
	(0.000)***	(0.000)***	(0.000)***
Observations	131	87	43
R^2	0.031	0.023	0.008

Robust p-values in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%

In a post-experiment questionnaire, subjects reported spending on average $13 on a bottle of wine, with a standard deviation of about $6. Only two of 266 subjects reported spending $40 or more. Only about 5% reported spending more than $20. In the light of this, the $40 must be considered expensive relative to what the subjects usually spent on wine. By contrast, 16 subjects reported spending 5$ or less on average, and 40 % reported spending $10 or less.[60] Hence, the treatment effect of the low price cannot be considered to be directly proportional to the treatment effect of the high price – i.e., it is possible that the cheap wine simply wasn't cheap enough. Subjects were asked to indicate their average weekly consumption of wine (number of glasses; frequency in parenthesis): < 1 (33%), 1-3 (40%), 4-6 (21%), 7-10 (6%), or > 10 (0%).

4. DISCUSSION

Consumers' perceptions of objective price-quality relationships are not always very accurate, and this can have important implications. In the marketplace, consumers typically face vast amounts of information about the good they are about to consume. Price may be one of the more salient types of information, and if many people are not ready to expand time and effort to investigate the price-quality relationship, as suggested by Alpert (Alpert 1971), then this leaves room for the use of price as an advertising tool, in a way that may be unrelated to the objective quality of the good.

We find that women assign considerably higher ratings to a wine if they are informed that it is expensive before tasting it. If they are informed that a wine is expensive after tasting it, assigned ratings are still higher than in the blind condition, but the difference is not statistically significant. When the wine is cheap, we do not find any negative effects of being informed about the price. For male tasters, we do not find any significant effects of knowing about the price – high or low – on average ratings.

Our main finding should surprise few: knowledge about the high price of a good can affect how it is experienced. In a world where luxury goods manufacturers routinely incorporate easily recognized logotypes into their designs, it can safely be assumed that knowledge about the high price of a good is considered a positive attribute that may confer status on its owner (Frank 1999). In addition, many consumers use a price-quality heuristic that leads them to expect higher prices to be correlated with better quality. Tasting wine has been shown to be an ambiguous experience for many, if not all, consumers. Objective measures of wine quality are not easily defined; consumer tastes with regard to wine are highly heterogeneous. Extrinsic information, such as the price of the good, is likely to play

[60] There were no observable gender differences in spending behavior.

a particularly important role when consumers are less confident in their own perceptions of quality.

In our view, the absence of a significant corresponding negative effect for a low price is most likely due to the design of our treatment, and not indicative of a deep asymmetry in how people react to high and low prices. In the post-experiment questionnaire, subjects reported their average level of spending on wine. The expensive wine was considerably higher than this average expenditure. The cheap wine, by contrast, was not below average expenditure in a way that can be considered proportional. In other words, most of our subjects typically consumed cheap wine. It is not surprising then that being informed about the cheap price did not have significant effects on ratings. It could be argued that a $5 wine is probably more in line with what tasters in the blind setting are used to drinking and would expect to be offered, compared to a $40 wine.

With regard to the gender difference, our finding can be interpreted in two ways: (1) There is no gender difference. Either the female price effect is a false positive or the absence of a male price effect is a false negative. (2) Men and women respond differently to social cues, including status concerns regarding positional goods. It is not self-evident that men and women should have evolved to react the same way to such cues, and ample experimental evidence indicates that such differences exist. In our view, the second explanation is at least as plausible as the first, and merits further exploration.

Our study builds on previous research on the relationship between the price and the subjective experience of wine, in particular Goldstein et al. (2008) and Plassmann et al. (2008), through the application of a methodology used in marketing research. That marketing actions can affect the experience of a good is in itself not a novel finding. Marketing research has for a long time sought to schematize and empirically evaluate the interaction of top-down cognitive processes, to which extrinsic information is addressed, with bottom-up sensory processes, i.e., the experience of the intrinsic qualities of the good.

Attribute information may lead consumers to invest more effort when experiencing the good (Hoch & Ha 1986). We did not control for the amount of time spent tasting the wine. It should also be noted that neither our study nor Plassmann et al. (2008) provides much detail about how expectations, once formed, interact with first-hand experience of a good. We do not know whether our subjects were actively searching for confirmatory evidence of an expensive/nice taste, or whether the wine simply tasted better during the actual tasting, such that the cognitive work on expectations occurred while processing the price information rather than while tasting. Future research should seek to shed more light on this process. We also encourage future research exploring whether our findings extend to other types of goods, and in particular whether the difference in how men and women respond to attribute information is product-specific and indicative of a more general difference in preferences between men and women.

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