ESSAYS ON RISK AND SOCIAL PREFERENCES: EVIDENCE FROM GENES, CULTURE, AND STRATEGIC INTERACTIONS

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DECLARATION

I hereby declare that this thesis is my original work and it has been written by me in its entirety. I have duly acknowledged all the sources of information which have been used in the thesis.

This thesis has also not been submitted for any degree in any university previously.

LU Yunfeng 26 Feb 2015

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Summary

Risk and social preferences are the fundamental blocks in behavioral economics. The three essays in this dissertation study people's risk and social preferences from an empirical and experimental perspective. We use biological data, in addition to observable choice data and field data, to investigate the determinants of risk and social preferences as well as factors that may influence people's behavior in several decision making settings.

In Essay 1, we examine how the level of serotonin receptor 2A (*HTR2A*) gene expression in blood influences people's risk attitude elicited in incentivized decision making tasks. We estimate structural models of prospect theory, and show that *HTR2A* is associated with the loss aversion parameter. The additional results of association between *HTR2A* and two personality measures Neuroticism as well as Harm Avoidance gave further support for the main finding. Finally we validated the blood genomics approach by showing that Single Nucleotide Polymorphism (SNP) variation is correlated with overall *HTR2A* expression.

In Essay 2, we investigate the rice culture hypothesis using the observed choice behavior for several experimental economics games in China. It has been proposed (Talhelm et al., 2014) that a history of rice farming makes cultures more interdependent while wheat farming makes cultures more independent, and that these longstanding agricultural

practices continue to influence cultures into the modern era. We find that the difference of cooperative behavior in the public goods game is explained by the extent of rice culture locally, proxied by the proportion of land used for rice farming. The rice culture theory is further corroborated in examining non-choice data relating to cooperativeness from a national representative survey data, China Family Panel Studies.

Essay 3 studies behavior in a two-stage matching pennies game where players face both objective risk and strategic uncertainty. We examine the effect of varying stake size in an experimental setting and show that the observed stake-size effect can be compatible with equilibrium behavior derived from recursive expected utility theory or quantal response model, but not from a standard expected utility specification.

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Chapter 1

Peripheral Serotonin Receptor 2A (*HTR2A*) Gene Expression and Financial Risk Preferences: Association with Loss Aversion, Anxiety-Related Personality Traits and Polymorphism[1]

1.1 Introduction

Across lifespans as individuals, and as a species, humans from their very beginnings on the savannahs of East Africa have been faced with decisions, which invariably involve some risk. Indeed decision-making under risk to this day is ubiquitous in our daily life. Some people invest in risky financial markets weighing the chance of gain and loss whereas other keep their money in low yielding bonds and bank deposits. Some people go for the longshot and bet on the state lottery but also buy insurance to avoid the low risk of rare events such as earthquakes. Facing these decisions, people vary greatly in their risk attitude. Some of us avoid risks if at all possible, whereas others are risk prone seeking out risky financial investment and the longshot gamble.

[1] This is a joint work with Mikhail Monakhov, Poh San Lai, Soo Hong Chew, and Richard Ebstein. We thank Anne Chong, Zhang Xing, and Tang Rong for assistance in data collection, Mikhail Monakhov, Aileen Pang Yu Wen, Lye Hui Jen, Xiong Gaogao, Zhu Qingdi and Ping Yuan – for assistance in DNA extraction and genotyping, Roy Chen, Song Changcheng, and Zhong Songfa for insightful comments and suggestions in the data analysis. This study was supported by grants from AXA Research Fund ("The Biology of Decision Making under risk"), John Templeton Foundation (ID: 21240), Singapore Ministry of Education ("The Genetic, Neuroimaging and Behavioral Study of Human Decision Making") and National University of Singapore ("Decision Making Under Urbanization: A Neurobiological and Experimental Economics Approach" and Start-Up grants to R.P.E. and S.H.C.).

To understand such complex choice behaviors under risk, several generations of social scientists have developed theories intended to capture the common features of decision-making but also accommodating the widespread observed individual differences in people's behavior. The most important of these theories is expected utility theory developed by John von Neumann and Oscar Morgenstern (1944). The theory assigns a utility number to each possible outcome in a gamble, and adds each gamble by weighing the probability of its occurrence. It uses an index of curvature in the utility function to measure individual differences in risk attitude. The theory is widely accepted in social sciences, and has found numerous applications. However, accumulating empirical evidence such as the Allais Paradox (Maurice Allais, 1953), challenged the expected utility theory as a complete explanation of real-life human choice behavior. Several non-expected utility theories (Chris Starmer, 2000) have emerged as alterative hypotheses and among the most important and influential is prospect theory (PT). Kahneman and Tversky (Daniel Kahneman and Amos Tversky, 1979, Amos Tversky and Daniel Kahneman, 1992) proposed in prospect theory to include loss aversion and probability weighting towards a deeper understanding of human decision-making. Prospect theory has generated a vast literature enabling a fuller appreciation of choice behavior under risk.

More recently, studies of financial risk attitude have taken a biological turn and explanations at the neural level (J. C. Dreher, 2007, M.

Hsu et al., 2005, B. Knutson and P. Bossaerts, 2007, B. Knutson and S. M. Greer, 2008, S. M. Tom et al., 2007, S. Zhong et al., 2012) have been sought towards a richer understanding of the brain regions underpinning decision-making. Many of these later investigations have leveraged behavioral economic tasks coupled with neural imaging and neurogenetic approaches spawning two emerging disciplines, neuroeconomics (C. F. Camerer, 2007, G. Loewenstein et al., 2008, R.P. Montague, 2007) and more recently, genoeconomics (D. J. Benjamin et al., 2012, DJ Benjamin et al., 2007, R. P. Ebstein et al., 2010, A. Navarro, 2009). Neurogenetic approaches to better understand financial decision-making have provisionally identified elements of dopaminergic (A. Dreber and C. L. Apicella, 2009, C. Frydman et al., 2011, C. M. Kuhnen and J. Y. Chiao, 2009) and serotonergic (L. G. Crisan et al., 2009, K. Doya, 2008, C. M. Kuhnen and J. Y. Chiao, 2009, C. M. Kuhnen et al., 2013) neural transmission as likely playing a role in choice behavior involving risk.

These neurogenetic approaches have tentatively identified candidate genes such as the dopamine receptor type 4 (*DRD4*) (A. Dreber and C. L. Apicella, 2009, C. M. Kuhnen and J. Y. Chiao, 2009), the serotonin transporter (*SLC6A4*) (C. M. Kuhnen, G. R. Samanez-Larkin and B. Knutson, 2013) and monoamine oxidase A (*MAOA*) (C. Frydman, C. Camerer, P. Bossaerts and A. Rangel, 2011, S. Zhong et al., 2009a) as contributing to financial risk attitude. However, given the moderate heritability of most complex traits, in which environment plays an important role, the sole pursuit of genetic markers alone may fail to reveal the fullness of phenotypic variance (T. A. Manolio et al., 2009, M. H. van Ijzendoorn et al., 2011). A complimentary approach is to measure biomarkers (D. S. Tylee et al., 2013) in accessible tissues such as blood. Gene expression, which reflects both hereditable and environmental influence, is a particularly attractive target. Measurement of mRNA levels is likely to capture more of the phenotypic variance, both genomic and epigenetic than a unitary gene based approach. Most importantly, expression levels of many genes show good correspondence between peripheral blood and brain (I. S. Kohane and V. I. Valtchinov, 2012, B. Rollins et al., 2010, P. F. Sullivan et al., 2006, D. S. Tylee, D. M. Kawaguchi and S. J. Glatt, 2013, C. H. Woelk et al., 2011). These considerations have catalyzed an increasing number of investigations demonstrating a relationship between peripheral transcription of both specific candidate genes as well as whole genome expression and many behavioral syndromes (M. Ayalew et al., 2012, Stephen J. Glatt et al., 2012, Stephen J. Glatt et al., 2013, S. M. Kurian et al., 2011, Y. Kuwano et al., 2011, H. Le-Niculescu et al., 2007a, H. Le-Niculescu et al., 2009, H. Le-Niculescu et al., 2007b, D. Mehta et al., 2011, M. Uddin et al., 2010, G. Ursini et al., 2011, Z. Yi et al., 2012). Indeed, so-called ‘blood genomics’ is becoming an important tool in dissecting complex behaviors. However, no studies to our knowledge have yet leveraged blood genomics towards understanding financial decision-making.

In the influential article of P. F. Sullivan, C. Fan and C. M. Perou (2006), the authors cautiously note that gene expression in blood "is neither perfectly correlated and useful nor perfectly uncorrelated and useless with gene expression in multiple brain tissues". They suggest that a circumspect employment of mRNA measurements in blood may index gene expression in some brain regions when it is certain that the gene of interest is expressed in both tissues. One of the genes specifically noted by them is the serotonin 2_A (5-HT_{2A}) receptor (*HTR2A*). *HTR2A* is expressed in both prefrontal cortex and whole blood suggesting that measurement of whole blood *HTR2A* mRNA levels would be a good surrogate for brain expression. The 5-HT_{2A} receptor has been the focus of keen interest in human behavioral studies including studies of schizophrenia (B. H. Ebdrup et al., 2011), borderline personality disorder (U. W. Preuss et al., 2001), mood disorders (L. Gu et al., 2013),suicidal behavior (N. Antypa et al., 2013) and aggression (Sophie da Cunha-Bang et al., 2013). Evidence from a variety of sources especially links 5-HT_{2A} to schizophrenia. For example, 5-HT_{2A} receptors have been a suggested as targets for atypical neuroleptic drugs (H. Y. Meltzer, 2012, T. A. Mestre et al., 2013); dysregulated 5-HT_{2A} receptor regulation as well as mRNA synthesis has been observed in schizophrenia (A. L. Lopez-Figueroa et al., 2004, C. Muguruza et al., 2013); receptors mediates the hallucinogenic effects of psilocybin (M. Kometer et al., 2013); and a meta-analysis of *HTR2A* polymorphisms suggests association with schizophrenia (G. Blasi et al., 2013, L. Gu, J. Long, Y. Yan, Q. Chen, R. Pan, X. Xie, X. Mao, X. Hu, B. Wei and L. Su, 2013). Beyond the evidence linking this receptor to abnormal behavior there are good reasons to expect that 5-HT_{2A} also has an important role in normal behavior including financial decision-making.

Firstly, the 5-HT_{2A} receptors are important in the regulation of brain dopamine (DA) transmission particularly in the mesocorticoaccumbens DA pathway, which originates in DA somata of the ventral tegmental area (VTA) and terminates in the nucleus accumbens (NAc) and prefrontal cortex (PFC) (M. J. Bubar and K. A. Cunningham, 2006). This system is crucial in reinforcement learning and brain reward pathways. 5-HT_{2A} receptors are mainly located post-synaptically and they provide stimulatory influence upon DA mesocorticoaccumbens output (M. J. Bubar and K. A. Cunningham, 2006). Secondly, 5-HT_{2A} receptors are located in the medial (m)PFC where they play a crucial role in amygdala regulation (P. M. Fisher et al., 2009). Thirdly, 5-HT_{2A} receptors have been directly observed in the amygdala itself (A. J. McDonald and F. Mascagni, 2007) and a polymorphic variant of the *HTR2A* receptor gene has been reported to modulate amygdala response to negative affective facial stimuli (B. T. Lee and B. J. Ham, 2008).

The overall importance of serotonin in decision-making (N. D. Daw et al., 2002, K. Doya, 2008) coupled with the vital role of 5-HT_{2A} receptors in regulating not only serotonergic but also dopaminergic neurotransmission in relevant brain regions discussed above, positions transcription of this gene to play a vital role in contributing to individual differences in risk attitude. In the current study we examined as a proxy for brain expression levels of *HTR2A* mRNA in blood from 205 university students, and compared the transcription of this gene to students' choices on 5 behavioral economic tasks designed to measure risk attitude. Notably, we used structural models across these five risk tasks to extract the risk phenotype for the genetic analysis. Additionally, as a further check of the ecological validity of *HTR2A* mRNA as a proxy for choice behavior we also examined the relationship between this measure and personality traits using the neuroticism in Big Five and Harm Avoidance in the Temperament Character Index or TCI (C.R. Cloninger et al., 1994). Plausibly both risk attitude and personality would also be expected to correlate with *HRT2A* gene expression.

1.2 Materials and Methods

1.2.1 Experimental Tasks

From 2010 to 2011, we conducted a large-scale behavioral experiment to study people's decision-making behavior at the National University of Singapore. All the risk choices follow the rubrics of experimental economics and are incentivized with money and transparent to the participant. Altogether we have 5 tasks that are directly related with risk (please refer to 1.5.1 Appendix A for the detailed experimental instructions). We denote them from A1 to A5, which record people's binary choices in the moderate gain domain, the moderate loss domain, the longshot gain domain, the longshot loss domain, and the mixture of gain and loss domains respectively. For each task there are 10 choices, while in each choice the subject chooses between a two-outcome lottery (Option A) and a certain amount of money (Option B). The Table 1.1 summarizes these choices.

Table 1.1 Choices in the Five Tasks

Task	**Option A**				**Option B**
	Probability 1	**Prize 1**	**Probability 2**	**Prize 2**	**Certainty**
A1	50%	$60	50%	$0	$15 ~ $35
A2	50%	-$15	50%	$0	$-8 ~ $-6.4
A3	1%	$200	99%	$0	$0.5 ~ $9
A4	2%	-$30	98%	$0	$-2 ~ $-0.1
A5	50%	$30	50%	-$16	$-3 ~ $10

1.2.2 Lab Procedures for DNA Genotyping and Gene Expression

Blood samples were collected by venipuncture, into EDTA tubes. DNA was extracted using QIAamp DNA Blood Midi Kit (Quiagen). SNPs were genotyped using HumanOmniExpress-12 v1.0 DNA Analysis Kit (Illumina Inc., San Diego, CA) in the Genome Institute of Singapore.

For extraction of RNA, blood samples were collected into Tempus tubes and total RNA was extracted using Tempus™ Spin RNA Isolation Kit (Applied Biosystems). cDNA was generated using QuantiTect Reverse Transcription kit (Quiagen) and quantified with Quant-iT OliGreen ssDNA Kit (Invitrogen). Gene expression was measured in Sequenom laboratory (Brisbane, Australia), using competitive PCR and MassARRAY technology. Assays were run in quadruplicates, with 6-log dynamic range titration curve. To select reference genes for normalization, expression levels of 12 housekeeping genes were measured in 44 samples. Based on a GeNORM analysis, TATA Box Binding Protein (*TBP*), Fumarate hydratase (*FH*), and Lactate dehydrogenase A (*LDHA*) were identified as being the most stably expressed. Expression values of *HTR2A* were normalized relative to expression of *TBP*, *FH* and *LDHA*, using geometric mean approach as described in (J. Vandesompele et al., 2002).

1.3 Results

1.3.1 Data

There are 205 subjects in our sample. The switching point in each of the 5 tasks is a simple measure of risk attitudes. For example, the number 3 in A1 indicates that the subject chooses the lottery in the first 3 choices, and switches to the various certain payoffs in the later 7 choices. Hence when bigger numbers indicate that the subject is less risk averse. In this paper, a simple risk measure is the switching point in each task, and *HTR2A* is the log of the concentration of *HTR2A* mRNA in blood. The

HTR2A concentration is measured as number of molecules of mRNA (messenger RNA) of gene *HTR2A* in the sample of total RNA (RNA from all genes including *HTR2A*) extracted from blood. Higher number of mRNA molecules corresponds to higher gene expression viz. more active gene. The variable "Female" is a dummy variable with "1" denoting female subjects, while "0" meaning male subjects. The following Table 1.2 is the descriptive statistics on the main variables in this study.

Table 1.2 Summary Statistics

Variable	Observation	Mean	Std. Dev.	Min	Max
A1	205	5.14	2.75	0	10
A2	200	6.56	2.98	0	10
A3	201	5.82	3.17	0	10
A4	204	6.48	3.75	0	10
A5	165	4.72	3.23	0	10
HTR2A	205	2.96	0.95	-0.891	4.92
Female	205	0.47	0.50	0	1

The switching points reveal a fourfold risk pattern in Table 1.3. In Task A1, we can infer that 74.6% of the subjects are strictly risk averse, and the remaining 25.4% are risk neutral or risk loving. This suggests that on average our subjects are risk averse in the moderate gain domain. On the contrary, in Task A2 there are only 14% of the subjects are risk averse, which suggests that on average subjects are risk loving in the moderate loss domain. In Task A3, 74.1% of the subjects are risk neutral or risk loving, and this suggests that many subjects prefer to buy risky lotteries in the longshot gain domain. In Task A4, 39.7% of the subjects are risk averse, which has much higher proportion than those in Task A2.

This means subjects are more risk averse when they faced with a small probability of losing money. Overall the pattern from Task A1 to Task A4 is similar to the fourfold risk pattern described by Tversky and Kahneman (1992). Hence, the use of prospect theory to interpret our results makes good sense and appears an eminently appropriate strategy in the current study.

Table 1.3 Switching Points in the Five Tasks

Task	A1	A2	A3	A4	A5
	Moderate gain	Moderate loss	Longshot gain	Longshot loss	Mixture gamble
Risk aversion	153 74.6%	28 14%	52 25.9%	81 39.7%	131 79.4%
Risk neutral or Risk loving	52 25.4%	172 86%	149 74.1%	123 60.3%	34 20.6%
Observation	205	200	201	204	165

1.3.2 Econometric Models

The above approach which separately examines each risk task has several shortcomings: (1) the measure of risk attitudes using switch point is coarse and, importantly, is not directly related with the parameters important in utility theories; (2) an underlying risk attitude named loss aversion is not captured by separately analyzing each distinct risk task and (3) we cannot quantitatively evaluate the impact of *HTR2A* gene expression on people's risk choices. However, the structural estimation approach, which enables combining all 5-risk tasks into a single economic model, crucially will generate an estimation of the deep parameters represented in utility functions.

Our experimental tasks involve both loss and gain decisions, which leads to a natural reference point. According to Amos Tversky and Daniel Kahneman (1992), we assume the value function over the certain outcome x has the following power function:

$$u(x) = \begin{cases} x^{\alpha}, if\ x \geq 0 \\ -\lambda(-x)^{\alpha}, if\ x < 0. \end{cases} \quad (1)$$

Here α is the parameter of the utility function curvature, λ is the parameter for loss aversion, and x is the lottery prize in the experiment. This utility function has the property of constant relative aversion (CRRA), so α <1 means risk loving, α =1 means risk neutral, and α >1 means risk averse. The identification of the loss aversion parameter λ comes from the mixed lottery Task A5.

It also has a probability weighting function that adopt the following form:

$$w(p) = p^{\gamma}/[p^{\gamma} + (1-p)^{\gamma}]^{1/\gamma} \quad (2)$$

Since from Task A1 to A5 the probabilities of the lotteries vary from moderate to longshot, it provides the identification of γ.

The subjects evaluate the lottery and the certainty money, and make the choice according to the function:

$$\Delta PT = PT_L - PT_C = \sum_k w(p(k))\times u(k) - u(c), for\ k = 1{,}2.$$

To account for the random error in the real choice data, we add a stochastic item μ into the log likelihood function:

$$lnL(\alpha, \lambda, \gamma, \mu, X) = \sum_i lnL_i$$

$$= \sum_i [(ln\Phi\ (\Delta PT/\mu)\times I(y_i = 1)) + \ln\ (1 - (\Delta PT/\mu)\ )\times I(y_i = 0))],$$

where Φ(.) is the CDF of the usual logit function, I(.) is the index function, y_i=1(or 0) indicates the choice of lottery (or certainty) in one task, μ is a noise parameter (John D Hey and Chris Orme, 1994), and X is a vector of individual characteristics including gender, age, and *HTR2A* gene expression level.

In addition, we assume that the loss aversion parameter λ and risk aversion parameter α are a linear function of the individual characteristics, which identify their impacts to λ and α.

$$\lambda = Costant + \lambda_1\times HTR2A + \lambda_2\times Female + \lambda_3\times Age \qquad (3)$$

$$\alpha = Costant + \alpha_1\times HTR2A + \alpha_2\times Female + \alpha_3\times Age \qquad (4)$$

1.3.3 Estimation Results

We estimated the structural models of prospect theory with maximum likelihood estimation[2], considering the cases of with and without the covariates of *HTR2A* gene expression, gender, and age. From Table 1.4, we observe that in equations (1), the constant terms of our main

[2] We used STATA version 12 here.

parameters α, λ, and γ are all statistically significant at the 1% level. The coefficients are reasonable and consistent to the existing literature – the loss aversion parameter λ is 1.64 whose magnitude is moderate, and α is 0.91 which means that the subjects are loss averse. This suggests that the prospect theory performs well in our sample. To investigate the impact of *HTR2A* on loss aversion parameter λ and risk aversion parameter α, we add *HTR2A*, gender, and age as the covariates of λ and α. The coefficient of *HTR2A* in λ is positive and marginal significantly different from 0 at the 10% level (p-value is 0.064), and *HTR2A* in α is not significantly different from 0 (p-value is 0.158). From these results, it is evident that the main impact of *HTR2A* is actually through loss aversion parameter λ.

We focus on the impact of *HTR2A* on λ in equation (3), and find that *HTR2A* is also positive and significant at the 10% level (the p-value is 0.08). We know that the *HTR2A* has the similar coefficients as those in equation (2), and albeit the significance is slightly decreased.[3]

This is the most important result to emerge from the structural equation modeling viz., the coefficients of *HTR2A* in λ, which suggests that people with higher *HTR2A* gene expression will be more loss averse. In addition, we notice that the "Female" dummy variables for λ in Equation (2) and (3) are significant at 5% level, which indicates a gender effect: female seems to be more loss averse in our sample.

[3] In 1.5.2 Appendix B, we demonstrate a reduced form estimation of the five risk tasks with the ordered logit regression. The positive association of *HTR2A* and Task A2 in the moderate loss domain confirms the relationship between *HTR2A* and loss aversion parameter in the structural estimation.

Since there is a strong gender effect in the above estimation, we divided the full sample into male and female subsamples. Table 1.5 shows that for the female subjects the estimated coefficient of *HTR2A* on λ is 0.24, and the it is statistically significant at the 5% level; while for the male subject, the estimated coefficient of *HTR2A* is 0.07, and it is not significantly different from 0. This suggests that *HTR2A*'s impact on loss aversion parameter λ mainly goes through the females.

Table 1.4 Structural Estimation of Prospect Theory

Variable	**(1)**	**(2)**	**(3)**
λ:			
Constant	1.64 ***	1.68 *	1.63 *
	(.06)	(0.88)	(0.94)
HTR2A		.11 *	0.12 *
		(.06)	(.06)
Female		.33 **	0.37 ***
		(.14)	(.14)
Age		-.02	-.03
		(.04)	(.04)
α:			
Constant	.91 ***	.78 ***	.91 ***
	(.01)	(.14)	(.01)
HTR2A		.01	
		(.01)	
Female		-.07 ***	
		(.03)	
Age		.01	
		(.01)	
γ:			
	.79 ***	.79 ***	.79 ***
	(.02)	(.02)	(.02)
Log(μ)	0.91 ***	0.88 ***	0.89 ***
	(.06)	(.06)	(.06)
Observation	10250	10250	10250
Log likelihood	-6045.12	-5957.40	-5989.80

Notes: Standard errors are in parentheses clustered at the individual subject level. *** means significant at the 1 percent level, ** means significant at the 5 percent level, and * means significant at the 10 percent level.

Table 1.5 Structural Estimation by Gender Subsample

Variable	(1) Both Gender	(2) Female	(3) Male
λ:			
Constant	1.68 *	2.64 **	1.20
	(0.88)	(1.08)	(1.13)
HTR2A	.11 *	0.24 **	0.07
	(.06)	(.09)	(.08)
Female	.33 **		
	(.14)		
Age	-.02	-.07	0.004
	(.04)	(.05)	(.05)
α:			
Constant	.78 ***	.59 ***	.59 ***
	(.14)	(.17)	(.17)
HTR2A	.01	-.004	0.02 *
	(.01)	(.02)	(.01)
Female	-.07 ***		
	(.03)		
Age	.01	.01 *	.002
	(.01)	(.01)	(.008)
γ:			
	.79 ***	.79 ***	.80 ***
	(.02)	(.03)	(.02)
Log(μ)	0.88 ***	0.83 ***	0.92 ***
	(.06)	(.09)	(.09)
Observation	10250	4800	5450
Log likelihood	-5957.40	-2765.90	-3177.79

Notes: Standard errors are in parentheses clustered at the individual subject level. *** means significant at the 1 percent level, ** means significant at the 5 percent level, and * means significant at the 10 percent level.

1.3.4 Robustness Checks

(1) Alternative probability weighting functions

We consider alternative probability weighting functions, and examine whether our main results still hold. Drazen Prelec (1998) proposed the following probability weighting function:

$$w(p) = \exp\left(-(-\ln p)^{\theta}\right)$$

The Equation (1) in Table 1.6 shows that this new probability weighting function fits the model quite well, and the values of λ and α are similar with those in Table 1.4. The Equation (2) in Table 1.6 adds the covariates, and the coefficient of *HTR2A* is also similar with the results in Table 1.4. This shows that our main results in Table 1.4 in robust to Prelec's alternative probability weighting function.

Another one is to assume there is no probability weighting, which means the following function:

$$w(p) = p$$

The Equation (3) and (4) in Table 1.6 show that our main results in Table 1.4 are still robust to the new model without probability weighing.

The overall message is that our estimated effect of *HTR2A* on loss aversion parameter λ is not driven by the probability weighting function.

Table 1.6 Alternative Probability Weighting Functions

Variable	(1) Prelec function	(2) Prelec function with Covariates	(3) No Probability Weighting	(4) No Probability Weighting with Covariates
λ:				
Constant	1.64 *** (.06)	1.68 * (0.88)	1.72 *** (0.07)	1.74 * (0.96)
HTR2A		.11 * (.06)		0.12 * (.07)
Female		.37 *** (.14)		0.42 *** (.16)
Age		-.02 (.04)		-.02 (.04)
α:				
Constant	.92 *** (.01)	.78 *** (.14)	.92 *** (.02)	.74 *** (.17)
HTR2A		.01 (.01)		.01 (.01)
Female		-.07 *** (.03)		-.08 *** (.03)
Age		.01 (.01)		0.01 (0.01)
θ:	.85 *** (.01)	.85 *** (.01)		
Log(μ)	0.91 *** (.06)	0.88 *** (.06)	1.11 *** (.07)	1.08 *** (.07)
Observation	10250	10250	10250	10250
Log likelihood	-6032.64	-5944.79	-6198.91	-6120.06

Notes: Standard errors are in parentheses clustered at the individual subject level. *** means significant at the 1 percent level, ** means significant at the 5 percent level, and * means significant at the 10 percent level.

(2) Alternative risk tasks

If we only use Task A1, A2, and A5, we could still identify the loss aversion parameter λ in the prospect theory. As a robustness check, in Table 1.7 we show the results of structural estimation of prospect theory using Task A1, A2, and A5. Indeed, the coefficients of λ are similar with those in Table 1.4 and Table 1.6.

Table1.7 Alternative Risk Tasks

Variable	**(1) TK (1992) Probability Weighting**	**(2) Prelec Probability Weighting**	**(3) No Probability Weighting**
λ:			
Constant	2.09 *	2.09 *	1.58 *
	(1.12)	(1.12)	(.92)
HTR2A	.16*	.16 *	.12*
	(.08)	(.08)	(.06)
Female	0.49 ***	.49 ***	0.38***
	(.18)	(.18)	(.14)
Age	-.02	-.03	-.02
	(.05)	(.05)	(.04)
α:			
Constant	.92 ***	.92 ***	.67 ***
	(.21)	(.21)	(.16)
HTR2A	.014	.015	.01
	(.01)	(.014)	(.01)
Female	-.06 *	-.06 *	-.05
	(.04)	(.04)	(.03)
Age	.01	.01	.01
	(.01)	(.01)	(.01)
γ:			
	.55 ***	.15 *	
	(.02)	(.09)	
Log(μ)	1.83 ***	1.83 ***	0.88 ***
	(.13)	(.13)	(.07)
Observation	6150	6150	6150
Log likelihood	-3369.54	-3369.54	-3441.04

Notes: Standard errors are in parentheses clustered at the individual subject level. *** means significant at the 1 percent level, ** means significant at the 5 percent level, and * means significant at the 10 percent level.

1.3.5 Evidence from Personality Traits

(1) *HTR2A* and Harm Avoidance

To check the ecological validity, domain specificity and generalizability of the relationship between risk phenotype captured in behavioral economic tasks and *HTR2A* expression, we next examine a 'loss side' phenotype captured in pencil and paper measured personality traits including Neuroticism in the Big Five scale and Harm Avoidance in the Temperament and Character Inventory (TCI) scale. The Big Five personality scale includes five factors - openness, conscientiousness, extraversion, agreeableness, and neuroticism. Neuroticism measures the tendency to experience unpleasant emotions easily, such as anger, anxiety, depression, and vulnerability. High Neuroticism score is related with low tolerance for stress or aversive stimuli. The TCI scale includes five factors: novelty seeking, harm avoidance, reward dependence, persistence, self-directedness, cooperativeness, and self-transcendence. Harm avoidance measures anticipatory worry, fear of uncertainty, shyness, and fatigability. We collected the personality and demographic information in questionnaires after the behavioral experiments. Indeed, we observe significant correlation (coefficient=1.48, p=0.03, observations = 188, with control of gender, age) between *HTR2A* gene expression and Neuroticism (Figure 1.1). In addition, we also find that *HTR2A* gene expression is positively correlated (coefficient=2.25, p=0.112, observations = 170, with control of gender, age) with TCI Harm Avoidance (Figure 1.2).

Figure 1.1 The Scatter Points of Neuroticism and *HTR2A*

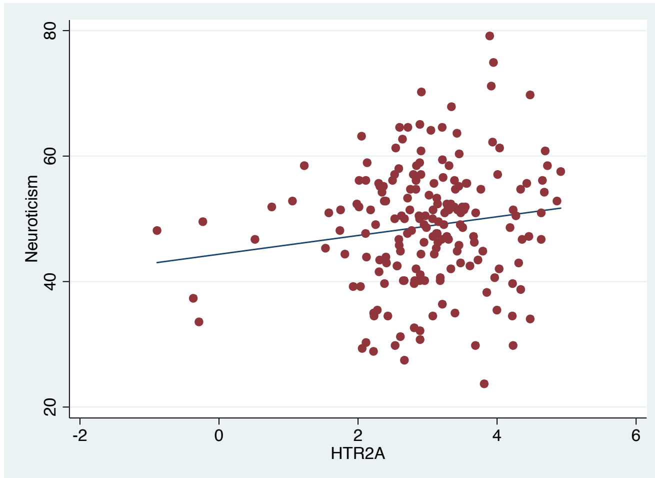
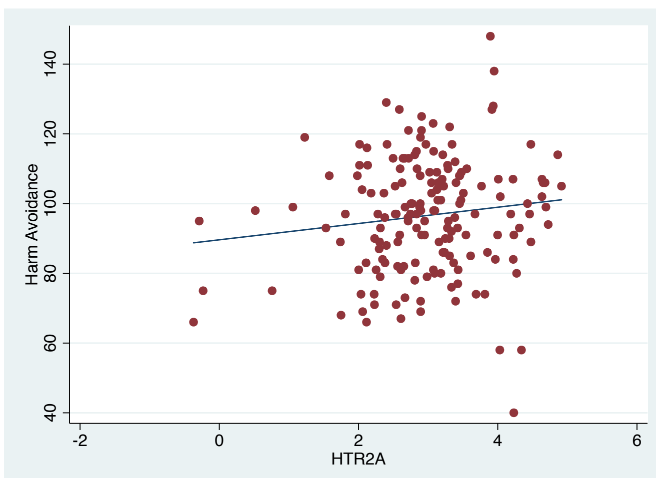


Figure 1.2 The Scatter Points of Harm Avoidance and *HTR2A*



(2) Anxiety related personality traits and loss aversion

Based on the previous results showing a correlation between Neuroticism as well as Harm Avoidance with *HTR2A* expression, we also examined the correlation between these two anxiety-related personality traits and each subject's predicted loss aversion parameter (λ). As shown in Figure 1.3 and Figure 1.4 both personality traits are significantly correlated with the loss aversion parameter (λ) derived from the prospect theory model in Table 4 with NEO neuroticism (in OLS linear regression, the slope coefficient=10.50, p=0.001) and TCI Harm Avoidance (in OLS linear regression, the slope coefficient=10.17, p=0.089).

Figure 1.3 The Scatter Points of NEO Neuroticism and λ

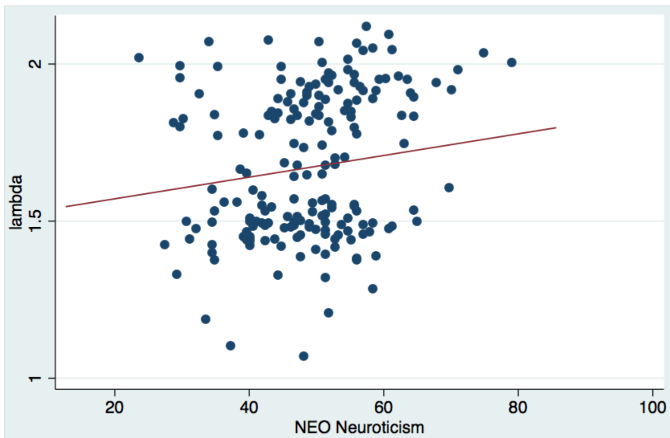
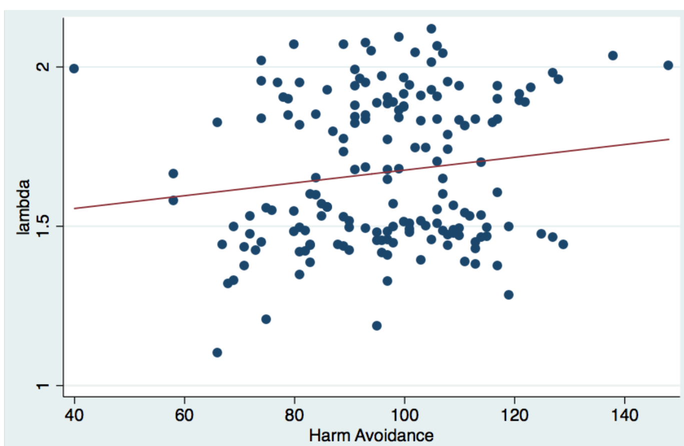


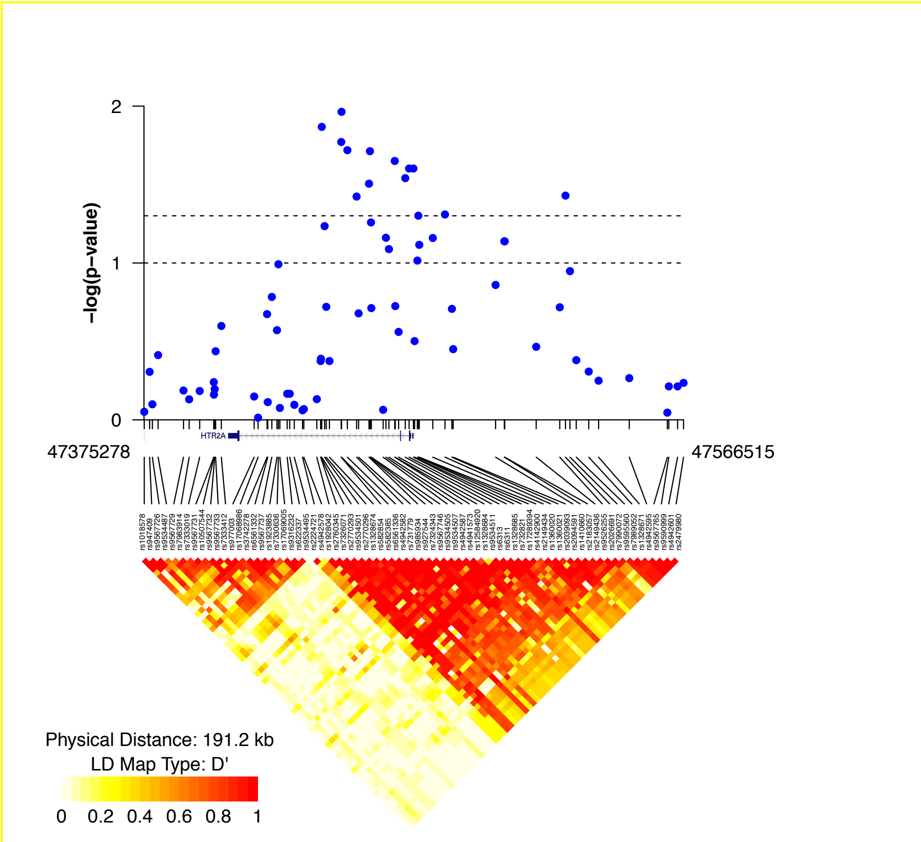
Figure 1.4 The Scatter Points of Harm Avoidance and λ



1.3.6 *HTR2A* Expression and Genetic Variation

The *HTR2A* gene contains 3 exons and 2 introns and is characterized by single nucleotide polymorphisms (SNPs) across the gene region. As shown in Figure 1.5, a number of SNPs are significantly associated with gene expression in blood cells.

Figure 1.5 LD Plot of *HRT2A* eQTLs in Blood



Notes: This figure shows the association between HTR2A gene expression and SNPs in HTR2A region. Every blue dot represents one SNP. The coordinates of dots on X-axis show location of SNPs on the chromosome. The coordinates on Y-axis show negative logarithm of p-value from tests of association between SNPs and HTR2A expression level (high values of -log(p) correspond to statistically significant associations). Upper dashed line indicates conventional significance threshold p=0.05. The location of HTR2A sequence that encodes HTR2A protein is shown immediately below x-axis. The heatmap on the lower pane shows extent of pair-wise LD (linkage disequilibrium) between SNPs. The D' (measure of LD) indicates the strength of pair-wise correlations between SNPs.

Of particular interest is one SNP rs6311 which is located in the 5' untranslated region of the gene. Cis-eQTL analyses demonstrated rs6311 modulates expression of the previously unannotated extended 5' UTR in human cortex (Ryan M Smith et al., 2013). Importantly, as shown in Figure 6 the direction of effect for the three genotypes of rs6311 in our blood samples is the same as in human cortex (Ryan M Smith, Audrey C Papp, Amy Webb, Cara L Ruble, Leanne M Munsie, Laura K Nisenbaum, Joel E Kleinman, Barbara K Lipska and Wolfgang Sadee, 2013). The similar direction of effect for both *HTR2A* expressed in blood and in human cortex observed here in a large Han Chinese sample strengthens the use of so-called 'blood genomics' as a proxy for brain expression for some, if not the majority of central nervous system expressed genes (E. Gardiner et al., 2012, H. Le-Niculescu, M. J. McFarland, S. Mamidipalli, C. A. Ogden, R. Kuczenski, S. M. Kurian, D. R. Salomon, M. T. Tsuang, J. I. Nurnberger, Jr. and A. B. Niculescu, 2007b, Y. Tang et al., 2004).

To further explore the relationship between eQTLs and *HRT2A*, and minimize the issue of multiple SNP testing, we carried out a principle components analysis (PCA) of all eQTL SNPs in this gene region. There are 10 SNPs in the *HTR2A* gene sequence, which are associated with *HTR2A* gene expression. For each of these SNPs we calculated a numerical score: number of minor alleles in a genotype (i.e., if SNP is A/G substitution and A is minor allele, then AA is takes value of 2, AG - 1 and GG - 0). Then we carried out a PCA analysis of these scores. PCA shows that there are 3 components with eigenvalue above 1 (that is, each of these 3 components explains variance in the data better than original SNP scores do). We then ran a regression with *HTR2A* expression as dependent variable, and 3 major principal components (and sex) as independent variables. The first component is significantly associated with gene expression and explains 58% of the variance. The Scree plot is shown in Figure 1.7.

We also examined the *HRT2A* SNPs for association with loss aversion parameter λ in the full sample. Of the 72 SNPs tested only one SNP rs1328685 with a nominal p value of 0.00013 survived the Bonferroni correction for multiple testing. Interestingly, this SNP has predicted functionality (YJ Ben-Efraim et al., 2013, F. Piva et al., 2010) albeit we do not observe effects of this SNP on expression in blood.

Figure 1.6 *HTR2A* Expression and rs6311 Genotype in Blood

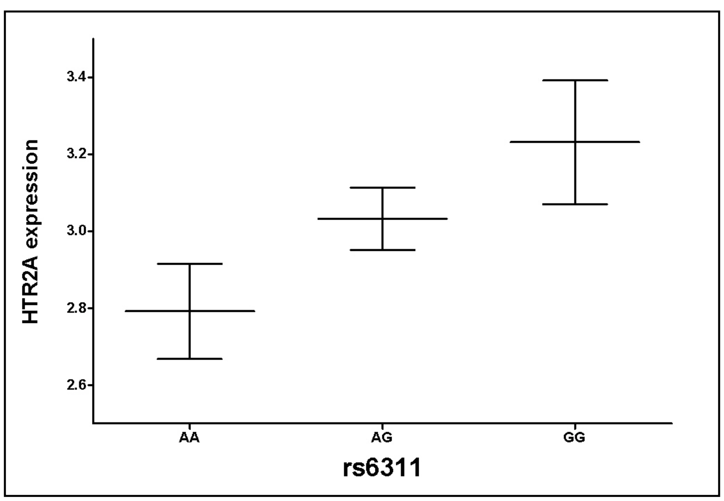
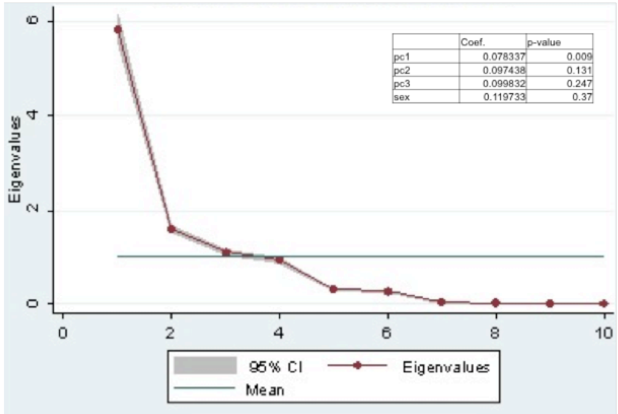


Figure 1.7 Scree Plot of PCA of *HTR2A* eQTLs



1.4 Discussion

Using a phenotype derived from structural estimation of five behavioral economic tasks based on incentivized gambles and designed to measure risk attitude, we observe a statistically significant correlation between *HTR2A* gene expression in blood and loss aversion. Greater peripheral *HTR2A* gene expression is correlated with greater loss aversion. Correlation is not, of course, causation. However, one of the main advantages of leveraging genetic data towards understanding the neural mechanisms underlying decision-making is that genetic variation is usually exogenous. In the current investigation, we mainly focus on the causal relationship between gene expression and risk attitude, and the coefficient of the relevant parameters is the consistent estimator under exogenous *HTR2A* variation. The correlation between a serotonin receptor expression and loss aversion is also theoretically plausible based on a neurochemical model we have proposed for valuation sensitivity over gains and losses (S.

Zhong et al., 2009b). In that model, we specifically indicated that serotonin modulates the sensitivity towards valuation of losses whereas dopamine modulates sensitivity towards valuation of gains. Regarding serotonin, our hypothesis is that 5-HT tone modulates sensitivity towards incremental loss and the higher the 5-HT tone, the higher the sensitivity towards incremental loss. We now further suggest, based on the current findings, the notion that increased expression of *HTR2A* leads to higher serotonergic tone, which in turn is correlated with higher loss aversion.

Many of the choices we make from starting a new business to investing in the stock market involve the chance of gaining or losing relative to our current position or status quo. Most people having to choose between keeping what we have or possibly losing money on a new venture, are risk averse. Indeed, laboratory experiments involving gambles for real money show that losses loom larger than gains unless the amount that can be gained is twice the amount that one can lose (Amos Tversky and Daniel Kahneman, 1992). Loss aversion has a very clean meaning in economic models, as we have discussed above, and there is a considerable challenge in translating this mathematical clarity to psychological and neural constructs. Nevertheless, evidence is accumulating regarding the neurochemical substrate of this phenomenon. In a recent review by (H. Takahashi, 2012), he discusses recent fMRI studies that have focused on the neural substrate of loss aversion (B. De Martino et al., 2010, P. Sokol-Hessner et al., 2013, P. Sokol-Hessner et al., 2009, S. M. Tom, C. R. Fox, C. Trepel and R. A. Poldrack, 2007). On the whole, regions involved in emotional processing the prefrontal cortex (PFC), the anterior cingulated cortex (ACC), the amygdala, the insula and striatal structures, are implicated in loss aversion. As he notes (H. Takahashi, 2012), the imaging evidence suggests that loss aversion is emotionally loaded which suggests an involvement of serotonergic brain pathways and more specifically, the 5-HT_{2A} receptor.

The 5-HT_{2A} receptor is widely expressed in the prefrontal cortex and after 5-$HT_{1A,}$ is the second most common serotonin receptor; it is predominantly expressed in pyramidal neurons (M. Amargos-Bosch et al., 2004). The cortex, ventral striatum, hippocampus, and amygdala are highly enriched in *HTR2A* expression. The cortex has been hypothesized as a "topdown" modulator of anxiety-related processes, given the extensive interconnections between the cortex and structures such as the hippocampus and amygdala. Recent functional imaging data in human subjects support this notion(S. Bishop et al., 2004, A. Heinz et al., 2005, J. M. Kent et al., 2005). In rodents, the excitatory effects of cortical 5-HT_{2A} apparently enhance anxiety (N. V. Weisstaub et al., 2006) as well as impulsivity (Catharine A Winstanley et al., 2004). In adult humans, 5-HT_{2A} binding is up-regulated in prefrontal cortex of subjects with mood disorders (RC Shelton et al., 2009). Notably, 5-HT_{2A} binding is correlated with personality traits such as neuroticism (V. G. Frokjaer et al., 2010, Vibe G. Frokjaer et al., 2008), which are risk factors for depression. In rodents, genetic deletion of cortical 5-HT_{2A} binding diminished anxiety levels (N. V. Weisstaub, M. Zhou, A. Lira, E. Lambe, J. Gonzalez-Maeso, J. P. Hornung, E. Sibille, M. Underwood, S. Itohara, W. T. Dauer, M. S. Ansorge, E. Morelli, J. J. Mann, M. Toth, G. Aghajanian, S. C. Sealfon, R. Hen and J. A. Gingrich, 2006). All of these just mentioned studies argue for a deep connection between 5-HT_{2A} and anxiety, a relationship that naturally supports a role for this receptor in partially mediating loss aversion. Surely anxious people are more prone to feel the pain of losses.

Altogether, it is a reasonable notion that decision-making takes place in the context of the brain's current and past emotion milieu and important recent investigations have shown that emotions indeed influence choice behavior(Jennifer S Lerner et al., 2004, Piotr Winkielman et al., 2005). Some recent studies underscore the role of emotion specifically in loss aversion (P. Sokol-Hessner, C. F. Camerer and E. A. Phelps, 2013, P. Sokol-Hessner, M. Hsu, N. G. Curley, M. R. Delgado, C. F. Camerer and E. A. Phelps, 2009). In the first study (P. Sokol-Hessner, M. Hsu, N. G. Curley, M. R. Delgado, C. F. Camerer and E. A. Phelps, 2009) participants were on average more aroused indexed by skin conductance response, per dollar to losses relative to gains, and the difference in arousal to losses versus gains correlated with behavioral loss aversion across subjects. In the second 'follow-up' study by the same group of investigators (P. Sokol-Hessner, C. F. Camerer and E. A. Phelps, 2013) they used fMRI and showed that behavioral loss aversion correlates with amygdala activity in response to losses relative to gains. Success in regulating loss aversion also correlated with the reduction in amygdala responses to losses but not to gains. The current findings demonstrating a relationship between *HTR2A* expression and loss aversion, coupled with the importance of 5-HT_{2A} receptors in emotional especially anxiety and amygdala regulation, may provide in part the neurochemical underpinning for the amygdala response to losses and not to gains (P. Sokol-Hessner, C. F. Camerer and E. A. Phelps, 2013).

An intriguing study of alexithymia (Peter A Bibby and Eamonn Ferguson, 2011) further strengthens the connection between emotion and financial decision-making specifically loss aversion. Alexithymia is a stable individual difference in peoples' inability to process emotional information (R. M. Bagby et al., 1994). Bibby and Ferguson (Peter A Bibby and Eamonn Ferguson, 2011) studied loss aversion indexed by gambles as well as by the 'riskless' endowment effect. It was found that the higher the alexithymia score the lower the loss aversion for both riskless and risky decisions. These results underscore that loss aversion is to some measure driven by ability to process emotional information and in the absence of 'emotion' people are considerably less sensitive to loss aversion. In a second study using a neurogenetic approach, association between the serotonin transporter and alexithymia scores was shown (M. Kano et al., 2012). Subjects with the s/l or s/s 5-HTTLPR version of the serotonin transporter, score lower on the alexithymia scale compared to subjects with the l/l polymorphism. Considering both the Bibby and Ferguson's finding (Peter A Bibby and Eamonn Ferguson, 2011) and those of Kano et al (M. Kano, T. Mizuno, Y. Kawano, M. Aoki, M. Kanazawa and S. Fukudo, 2012), they together strengthen the notion that subjects with higher synaptic serotonin levels (high 5-HT tone), due to a less efficient transporter (short version s/s or s/l), are more sensitive to loss aversion.

Pencil and paper personality measures offer a complementary perspective in understanding individual differences in decision-making and hence there is considerable interest in the relationship between personality traits and choice behavior. These different measures by economists and psychologists could ideally be combined towards a deeper understanding of human behavior (Lex Borghans et al., 2008). A number of previous studies have reported generally significant but weak correlations between personality traits and financial risk preferences (Jon Anderson et al., 2011, Anke Becker et al., 2012, A. Rustichini et al., 2012). As discussed in the article by Anderson et al (Jon Anderson, Stephen Burks, Colin DeYoung and Aldo Rustichini, 2011), attitudes to risk are mostly affected by Neuroticism: a higher Neuroticism score is associated with a higher aversion to risk and uncertain outcomes. Overall our results in the current investigation where we observe a correlation between the loss aversion parameter λ, derived from both EU and PT and anxiety-related personality traits measured by two widely employed personality inventories, the NEO and TCI, are consistent with previous findings regarding anxiety-related personality traits and economic risk attitude.

Importantly, we validated the blood genomics approach by showing that SNP variation is correlated with overall *HTR2A* expression. Multiple SNPs in the *HTR2A* gene region are associated with gene expression. To minimize the issue of multiple testing, we combined the SNP variation using PCA and show that the first principal component, which explains more than 50% of the variance, is significantly associated with overall *HTR2A* expression. One particular SNP which has been the focus of considerable study, rs6311 – also known as (-1438G>A), showed a similar genotype direction with respect to mRNA levels as has been observed in human cortex (Ryan M Smith, Audrey C Papp, Amy Webb, Cara L Ruble, Leanne M Munsie, Laura K Nisenbaum, Joel E Kleinman, Barbara K Lipska and Wolfgang Sadee, 2013). In both cortex and blood the G allele additively increases overall gene expression.

Interestingly, rs1328685 was significantly associated with the loss aversion parameter λ following stringent Bonferroni correction. In the study of Smith et al (Ryan M Smith, Audrey C Papp, Amy Webb, Cara L Ruble, Leanne M Munsie, Laura K Nisenbaum, Joel E Kleinman, Barbara K Lipska and Wolfgang Sadee, 2013) significant allelic expression imbalance in human cortex was observed for two SNPs in the extended HTR2A 5'UTR, rs1328685 and rs6311 albeit the evidence was strongest for rs6311. However, in the current study whereas rs6311 was associated with greater *HTR2A* blood expression, rs1328685 was not. Nevertheless, according to Piva et al (F. Piva, M. Giulietti, B. Nardi, C. Bellantuono and G. Principato, 2010) this SNP is a possible site for two transcription factors, GR and HNF4. The presence of the minor allele results in loss of the TF binding site for both rs1328685 and rs6311. GR is the receptor for the glucocorticoid receptor and HNF4 is a TF for many metabolic enzymes and proteins. It was reported that *HTR2A* is up-regulated in chronic fatigue syndrome through allele-specific expression modulated by transcription factors at critical sites in its promoter: an E47 binding site at position -1,438, (created by the A-allele of rs6311 polymorphism), a glucocorticoid receptor (GR) binding site encompassing a CpG at position -1,420, and Sp1 binding at CpG methylation site -1,224 (V. R. Falkenberg et al., 2011). Moreover, subchronic glucocorticoid treatment upregulates 5-HT_{2A} receptor density in human blood samples (Anders Kling et al., 2013). We suggest the notion that the impact of the rs1328685 SNP on loss aversion may be mediated early in development when the serotonin system has been shown to be sensitive to glucocorticoid levels (Delia M. Vázquez et al., 2012). These observations suggest that a worthwhile avenue for future research is the study of epigenetic signatures on the *HRT2A* gene which have been shown to regulate its expression (V. R. Falkenberg, B. M. Gurbaxani, E. R. Unger and M. S. Rajeevan, 2011). The significant association we observe between rs1328685 and the loss aversion parameter λ may be better understood following methylation analysis of

CpG sites in the *HRT2A* promoter region.

By combining a blood genomics approach, behavioral economic tasks and personality measures in a single study we are able to draw a fuller and more nuanced picture of the loss aversion parameter derived by structural estimation of prospect theory. Molecular explanations for loss aversion, which we provide in this study, provide the proximate explanation of the loss aversion construct, viz., 'how'. What are the neurochemical mechanisms underlying this parameter and how does loss aversion work at the brain level? Personality psychology provides a second level of explanation of the 'how' of loss aversion. Roberts et al (Brent W Roberts et al., 2007) define personality as "the relatively enduring patterns of thoughts, feelings, and behaviors that reflect the tendency to respond in certain ways under certain circumstances". We reveal in the current investigation an explanation of the 'how' not only at the most basic level of gene expression but notably extend our explanation to a higher construct, personality, and show that anxiety-related personality traits are correlated both with loss aversion but also with *HTR2A* gene expression. Importantly, *HTR2A* gene expression links the loss aversion parameter to serotonin neural pathways that underlie emotional behavior partially explaining how 'emotion' impacts financial decision-making. For the ultimate explanation of loss aversion and other economic biases we might turn to evolutionary theory (Peter Hammerstein and Edward H Hagen, 2005, Rose McDermott et al., 2008, Nick Netzer, 2009). Ultimate explanations are concerned with why a behavior exists – does it increase our fitness? A simple evolutionary explanation of loss aversion is perhaps described by the adage “a bird in the hand is worth two in the bush”. In our hunter gatherer days having made a kill and calculating the probability of a second kill, the best bet might be to hold on to the just acquired meal and not risk looking for another.

The current study has wider implications for understanding both the genetic as well as the environmental influences that jointly modulate financial decision-making. Although the importance of psychological insights in informing economic theory have steadily gained traction (Matthew Rabin, 1998), the same cannot be said for molecular genetic approaches in social sciences (D. J. Benjamin, D. Cesarini, M. J. van der Loos, C. T. Dawes, P. D. Koellinger, P. K. Magnusson, C. F. Chabris, D. Conley, D. Laibson, M. Johannesson and P. M. Visscher, 2012, DJ Benjamin, CF Chabris, EL Glaeser, V Gudnason, TB Harris, D Laibson, L Launer and S Purcell, 2007, E. Charney and W. English, 2012, A. Navarro, 2009). Some of the thorniest issues in applying molecular genetic approaches to complex behaviors are (1) small effect sizes (2) the interaction of genes with the environment, G x E and (3) epistasis or gene × gene interactions. We suggest that the approach taken in the current study by examining blood expression of a gene also expressed in brain overcomes some of the obstacles just cited in applying a neurogenetic strategy to revealing underlying mechanisms in economic concepts.

HTR2A blood expression is a measure not only of genomic influences but also epigenetic modifications of DNA. As defined in a recent review (R. Bogdan et al., 2013) "epigenetics refers to cell-specific changes in gene expression that are caused by factors (for example, methylation affecting gene transcription accessibility) other than the underlying static DNA sequence". We suggest the notion that blood expression of *HTR2A* can be considered an aggregate measure capturing genetic and epigenetic variables that is more informative than simply examining polymorphic variations at the level of DNA sequence.

1.5 Appendix

1.5.1 Appendix A: Experimental Instructions

SET A – Individual Decision Making

GENERAL INSTRUCTIONS

Set A comprises 22 tasks. The first 21 tasks are of the form illustrated in the table below. Each lists 10 choices to be made between a fixed Option A and a number of different Option B's. For each row, you are asked to indicate your choice by ticking A or B in the final column of the table. The first 21 tasks are of the form illustrated in the table below.

	Option A	Option B	Decision
1	A	B1	A ▯ B ▯
2	A	B2	A ▯ B ▯
3	A	B3	A ▯ B ▯
4	A	B4	A ▯ B ▯
5	A	B5	A ▯ B ▯
6	A	B6	A ▯ B ▯
7	A	B7	A ▯ B ▯
8	A	B8	A ▯ B ▯
9	A	B9	A ▯ B ▯
10	A	B10	A ▯ B ▯

You may make your decisions in any order and you may change your decisions at any time. Just indicate each revised decision clearly.

Selection of Section A tasks to be implemented: One out of the first 19 tasks (selected randomly by you) will be implemented. The final 2 tasks – Task 20 and Task 21 – will be implemented for two randomly selected 2 participants in the room.

You may now begin. Should you have questions during the experiment, please raise your hand. An experimenter will come to you and answer your questions individually.

DECISION SHEET A1

This situation calls for you to guess the color – red or black – of a card drawn randomly from a deck of 20 cards, comprising **10 black** cards and **10 red** cards.

Option A: If you make a correct guess, you receive $60; otherwise, you receive nothing. That is: **50% chance of receiving $60 and 50% chance of receiving $0.**

The **Option B** column lists the amounts you will receive for sure if you choose this option.

For each of the 10 decisions in the final column, please tick **(√)** your choice.

	Option A	Option B	Decision
1	50% of receiving $60, 50% of receiving $0	Receiving $15 for sure	A ☐ B ☐
2	50% of receiving $60, 50% of receiving $0	Receiving $19 for sure	A ☐ B ☐
3	50% of receiving $60, 50% of receiving $0	Receiving $23 for sure	A ☐ B ☐
4	50% of receiving $60, 50% of receiving $0	Receiving $25 for sure	A ☐ B ☐
5	50% of receiving $60, 50% of receiving $0	Receiving $27 for sure	A ☐ B ☐
6	50% of receiving $60, 50% of receiving $0	Receiving $29 for sure	A ☐ B ☐
7	50% of receiving $60, 50% of receiving $0	Receiving $30 for sure	A ☐ B ☐
8	50% of receiving $60, 50% of receiving $0	Receiving $31 for sure	A ☐ B ☐
9	50% of receiving $60, 50% of receiving $0	Receiving $33 for sure	A ☐ B ☐
10	50% of receiving $60, 50% of receiving $0	Receiving $35 for sure	A ☐ B ☐

DECISION SHEET A2

This situation calls for you to guess the color – red or black – of a card drawn randomly from a deck of 20 cards, comprising **10 black** cards and **10 red** cards.

Option A: If you make a correct guess, you lose $15; otherwise, you lose nothing. That is: **50% chance of losing $15 and 50% chance of losing $0.**

The **Option B** column lists the amounts you will receive for sure if you choose this option.

For each of the 10 decisions in the final column, please tick (√) your choice.

	Option A	**Option B**	**Decision**
1	50% of losing $15, 50% of losing $0	Losing $8.00 for sure	A ☐ B ☐
2	50% of losing $15, 50% of losing $0	Losing $7.80 for sure	A ☐ B ☐
3	50% of losing $15, 50% of losing $0	Losing $7.60 for sure	A ☐ B ☐
4	50% of losing $15, 50% of losing $0	Losing $7.50 for sure	A ☐ B ☐
5	50% of losing $15, 50% of losing $0	Losing $7.40 for sure	A ☐ B ☐
6	50% of losing $15, 50% of losing $0	Losing $7.20 for sure	A ☐ B ☐
7	50% of losing $15, 50% of losing $0	Losing $7.00 for sure	A ☐ B ☐
8	50% of losing $15, 50% of losing $0	Losing $6.80 for sure	A ☐ B ☐
9	50% of losing $15, 50% of losing $0	Losing $6.60 for sure	A ☐ B ☐
10	50% of losing $15, 50% of losing $0	Losing $6.40 for sure	A ☐ B ☐

DECISION SHEET A3

This situation involves your drawing randomly from a deck of cards comprising **9 black** cards and **1 red** card.

Option A: If you draw the red card with replacement twice, you receive $200. Otherwise, you receive $0. That is: **1% chance of receiving $200 and 99% chance of receiving $0.**

The **Option B** column lists the amounts you will receive for sure if you choose this option.

For each of the 10 decisions in the final column, please tick (√) your choice.

	Option A	Option B	Decision
1	1% of receiving $200, 99% of receiving $0	Receiving $0.50 for sure	A ☐ B ☐
2	1% of receiving $200, 99% of receiving $0	Receiving $1.00 for sure	A ☐ B ☐
3	1% of receiving $200, 99% of receiving $0	Receiving $1.80 for sure	A ☐ B ☐
4	1% of receiving $200, 99% of receiving $0	Receiving $2.00 for sure	A ☐ B ☐
5	1% of receiving $200, 99% of receiving $0	Receiving $2.20 for sure	A ☐ B ☐
6	1% of receiving $200, 99% of receiving $0	Receiving $3.00 for sure	A ☐ B ☐
7	1% of receiving $200, 99% of receiving $0	Receiving $4.00 for sure	A ☐ B ☐
8	1% of receiving $200, 99% of receiving $0	Receiving $5.50 for sure	A ☐ B ☐
9	1% of receiving $200, 99% of receiving $0	Receiving $7.00 for sure	A ☐ B ☐
10	1% of receiving $200, 99% of receiving $0	Receiving $9.00 for sure	A ☐ B ☐

DECISION SHEET A4

This situation involves your drawing one card randomly from a deck of cards comprising **49 black** cards and **1 red** card.

Option A: If you draw the red card, you lose $30. Otherwise, you lose $0. That is: **2% chance of losing $30 and 98% chance of losing $0.**

The **Option B** column lists **10 loss amounts** each corresponding to what you will **lose** for sure if you choose this option. (*Notice that the loss amounts are displayed in a descending manner.*)

DECISION: For each of the 10 rows, please indicate your decision in the final column with a tick (√).

	Option A	Option B	Decision
1	2% of losing $30, 98% of losing $0	Losing $2.00 for sure	A ▯ B ▯
2	2% of losing $30, 98% of losing $0	Losing $1.50 for sure	A ▯ B ▯
3	2% of losing $30, 98% of losing $0	Losing $1.20 for sure	A ▯ B ▯
4	2% of losing $30, 98% of losing $0	Losing $1.00 for sure	A ▯ B ▯
5	2% of losing $30, 98% of losing $0	Losing $0.80 for sure	A ▯ B ▯
6	2% of losing $30, 98% of losing $0	Losing $0.70 for sure	A ▯ B ▯
7	2% of losing $30, 98% of losing $0	Losing $0.60 for sure	A ▯ B ▯
8	2% of losing $30, 98% of losing $0	Losing $0.50 for sure	A ▯ B ▯
9	2% of losing $30, 98% of losing $0	Losing $0.30 for sure	A ▯ B ▯
10	2% of losing $30, 98% of losing $0	Losing $0.10 for sure	A ▯ B ▯

DECISION SHEET A5

This situation involves your guessing the color – red or black – of a card drawn randomly from a deck of 20 cards, comprising **10 black** cards and **10 red** cards.

Option A: You guess the color – black or red – of a card that you are about to draw from the deck of 20 cards. If you make a correct guess, you receive $30; otherwise, you lose $16. That is: **50% chance of receiving $30 and 50% chance of losing $16.**

The **Option B** column lists the amounts you can receive or lose for sure if you choose this option.

DECISION: For each of the 10 rows, please indicate your decision in the final column with a tick (√).

	Option A	Option B	Decision
1	50% of receiving $30, 50% of losing $16	Losing $3 for sure	A ☐ B ☐
2	50% of receiving $30, 50% of losing $16	Losing $1 for sure	A ☐ B ☐
3	50% of receiving $30, 50% of losing $16	Losing $0 for sure	A ☐ B ☐
4	50% of receiving $30, 50% of losing $16	Receiving $1 for sure	A ☐ B ☐
5	50% of receiving $30, 50% of losing $16	Receiving $2 for sure	A ☐ B ☐
6	50% of receiving $30, 50% of losing $16	Receiving $4 for sure	A ☐ B ☐
7	50% of receiving $30, 50% of losing $16	Receiving $6 for sure	A ☐ B ☐
8	50% of receiving $30, 50% of losing $16	Receiving $7 for sure	A ☐ B ☐
9	50% of receiving $30, 50% of losing $16	Receiving $8 for sure	A ☐ B ☐
10	50% of receiving $30, 50% of losing $16	Receiving $10 for sure	A ☐ B ☐

1.5.2 Appendix B: Ordered Logit Regression Results

We use the ordered logit regression analysis to examine the relationship between *HRT2A* expression and risk attitude. The dependent variables in the regressions are all integers and large values indicate subjects are more risk prone. Results are shown in Table A.

From Table A, we observe that for Task A1, the coefficient for *HTR2A* is positive and statistically insignificant. For Task A2, the coefficient for *HTR2A* is also positive and statistically significant at p<10% level, which indicates that greater *HTR2A* gene expression is correlated with less risk aversion over moderate loss. For the tasks A3, A4, and A5, the coefficients of *HTR2A* are not significant albeit for A4 and A5 the coefficient is negative.

Table A Ordered Logit Regression Results

Variables	A1	A2	A3	A4	A5
HTR2A	0.196	0.220*	0.205	-0.0343	-0.160
	(0.122)	(0.120)	(0.195)	(0.116)	(0.120)
Age	0.0397	-0.0838	0.0304	-0.0128	0.0432
	(0.0713)	(0.0839)	(0.0937)	(0.0955)	(0.0817)
Female	-0.413	0.528*	-0.300	0.274	-0.788***
	(0.270)	(0.316)	(0.298)	(0.278)	(0.286)

Notes: Standard errors are in parentheses. *** means significant at the 1 percent level, ** means significant at the 5 percent level, and * means significant at the 10 percent level.

Chapter 2

The Rice Culture Theory of Cooperative Behavior: Evidence from Incentivized Decision Making Tasks in China[4]

2.1 Introduction

The globalization phenomenon from widespread trans-continental tourism (Chris Cooper and Salah Wahab, 2005) to migration patterns (Nikos Papastergiadis, 2013) in North America and Europe and some East Asian countries has heightened awareness of both the similarities and differences between people from different cultures. Indeed, while cultural differences are both fascinating and intriguing they also present challenges for international business negotiations to the conduct of foreign affairs by nations and importantly assimilation of migrants striving to adapt to new cultures. Indeed, cultural differences especially between East and West have been well documented (Theodore M. Singelis, 1994) and impact subtly and not so subtly on cognitive styles (S. Kitayama and A. K. Uskul, 2011), decision making (J. Henrich et al., 2005) and choice behaviors (U. Gneezy et al., 2009). Interestingly, the study of such cultural phenomenon have even spawned a new field so-called cultural neuroscience (Heejung S Kim and Joni Y Sasaki, 2014). Many studies in cultural psychology and cultural neuroscience have focused on cultural

[4] This is a joint work with Soo Hong Chew and Richard Ebstein. We are very grateful to Roy Chen, Juin Kuan Chong, Haoming Liu, Chiu Yu Ko, Bin Miao, Jessica Pan, Slesh A. Shrestha, Aloysius Siow, Tuan Hwee Sng, Changcheng Song, Huojun Sun, Xing Zhang, and Songfa Zhong for their helpful comments and suggestions. All errors are our own.

differences between countries (Geert Hofstede et al., 1991, Keiko Ishii, 2013) but such studies are unavoidably confounded by extraneous variables such as ethnicity, diverse law and governmental systems and many other such factors. Hence, there is some advantage to focus on cultural differences in the same country especially if certain differences resulting from ethnicity, genetic background and governmental systems are minimized. This strategy would potentially reduce noise and generate less ambiguous findings.

We implement this strategy of examining the impact of cultural milieu within a single country using cooperative behavior in China and focusing in particular on difference in agricultural practices between rice paddy and wheat cultivation regions. Talhelm and his colleagues (T. Talhelm et al., 2014) hypothesized that rice farming encourages a culture of interdependency whereas wheat farming encourages greater independence among individuals. Moreover, these cultivation differences over historical time apparently become integrated into a region's culture and gradually develop into cultural adaptations which presumably have a lasting effect on individual behavior even into the modern era. Such cultural adaptations become the Weltanschauung of such regions characterizing a somewhat permanent collective pattern of behavior no longer dependent on any individual's experience with actual farming practices. We test elements of this rice culture theory by examining university students in Beijing representative of many Chinese provinces and dip into the toolkit of experimental economics to examine cooperative behavior. We further use a national survey to examine real-life cooperative behavior in a large non-student based population.

Rice along with wheat are among the most important food crops world wide and indeed rice ranks third in total food production (Papa Abdoulaye Seck et al., 2012). In China rice has a long history originating about 8200 years at the dawn of the world agricultural revolution (Xuehui Huang et al., 2012) and rice farming has become embedded in Chinese culture from the rice paddy to characterizing the national cuisine. The current study seeks to examine in depth the pervasive influence of rice cultivation on a distinguishing feature of human culture viz., cooperative behavior not based on kin relationships. A theoretical basis for a relationship between cooperation at the societal level and the rice paddy field is based on the evidence that cultivating rice requires much more labor input in comparison to other food crops such as corn or wheat. The irrigation needed for paddy rice is particularly demanding. Hsiao-Tung Fei (1939) originally observed that the irrigation system in the Yangtze River requires the cooperation of all the families in the village and families organized in turn to manually rotate the operation of the water wheels with the community-wide efforts.

In the current study we put to the test elements of the rice culture theory as it applies to cooperative behavior examining in depth such behavior from several data sets. The first data set is generated in the experimental economics tasks in a study by our group conducted in 2010 and 2012 in Beijing with university students representative of various provinces in China. These incentivized laboratory tasks were carried out following the rubrics of experimental economics and we suggest provide robust measures of social preferences. Our second in depth data analysis relied on the 2010 wave of the China Family Panel Studies, which provides a national representative sample and employs broad field measures of social behavior. Notably, the overall evidence from both experimental and field sources supports the prediction of the rice culture theory that subjects born in rice paddy regions of China are characterized by more cooperative behavior in comparison to students born in non paddy regions.

The paper proceeds as follows: Section 2.2 reviews the related literature; Section 2.3 shows the main empirical results; Section 2.4 discusses the implications of the results; and Section 2.5 concludes.

2.2 Literature

The evolution of cooperation among non-kin is an intriguing problem that is a continuing dilemma for evolutionary biologists, and social scientists including economists. Experimental economics seeks to model human choice behavior in the laboratory using incentivized and transparent behavioral tasks. In the realm of cooperation the public goods (PG) game has garnered particular attention for the representation of group interactions. In the simplest version of a PG game, the one round version, participants anonymously decide how much of their endowment to contribute to the public kitty and the tokens in the public pot are generally multiplied by more than 1 and less than the total number of players in the game and the total pot is divided by the number of players (Ananish Chaudhuri, 2011). Each player also retains the amount he did not contribute to the public kitty. The prediction of the Nash equilibrium in the one shot game is that people will contribute zero, while in lab experiments participants contribute between 40-60% of the optimal level although marked individual differences are observed from 0-100% of their endowment. Ananish Chaudhuri (2011) suggests that an important advance in our understanding of the psychology of participants in the PG game is the concept of "conditional cooperators whose contribution to the public good is positively correlated with their *beliefs* about the contributions to be made by their group members."

In the context of the current study viz., testing the rice theory as at least a partial explanation of human cooperation, we considered the one shot PG game as the most robust available experimental economic task that resonates with actual behavior in rice paddy cultivation where cooperation is crucial for the overall common good but some degree of free riding is always an alternative that participants may choose. Our overarching hypothesis is that participants characterized by an embedded rice culture norm would contribute more in a single shot PG game compared to individuals born in a non-rice paddy geographical region. Hence, the one shot PG is the benchmark laboratory task in the current study. However, as discussed below experimental economists have devised a number of prosocial laboratory tasks that offer additional insight into the motivations underlying contributions to the PG game and the evolution of human cooperation according to the rice theory.

One model is altruism (James Andreoni, 1989, 1990) which assumes that people directly derive utility from their prosocial behavior. Another is the inequity aversion model, proposed by Ernst Fehr and Klaus M Schmidt (1999), which argues that the prosocial behavior in many experimental games could be explained by the motivation to achieve equal allocation between the subject and others. Yet, a third model (Martin Dufwenberg and Georg Kirchsteiger, 2004, Matthew Rabin, 1993) captures people's reciprocity behavior using belief-based modeling. Gary Charness and Matthew Rabin (2002) added an efficiency motivation into consideration and showed that people often prefer a big pie in the in the prosocial context. All these models potentially deepen our understanding of individual differences in choice behavior exhibited in the PG game.

A series of studies using modified dictator games (James Andreoni and John Miller, 2002, Raymond Fisman et al., 2014, Raymond Fisman et al., 2007) showed that people exhibit marked heterogeneity in social preferences. Moreover, prosocial field behavior also has been shown to vary across countries. For example, in April 1996, the Reader's Digest magazine (reported by the Economist, June 22, 1996) dropped 20 cash-bearing wallets in each of 20 cities of western European countries and 10 wallets in each of 12 US cities, and found that the frequency of returning wallets differed systematically. These cross-country field observations have subsequently been validated by Stephen Knack and Philip Keefer (1997) with survey data.

Researchers use a variety of innovative designs to investigate the main determinants of preferences. Samuel Bowles (1998) argued that the markets and other economic institutions influence cultures and hence preferences. Joseph Henrich et al. (2001) used the index of market integration to explain the difference in people's prosocial behavior across cultures. Nancy Qian (2008) employed a difference-in-differences method to investigate how the increase of tea price will reduce the gender ratio unbalance in south China. Using historical field data, Alberto Alesina et al. (2013) investigated how agricultural patterns influence people's gender attitudes - societies that historically used the plough in agricultural production exhibit more unequal gender attitudes presumably since mainly men have the strength required for this type of cultivation. Using experimental economics tasks, Andreas Leibbrandt et al. (2013) compared competitiveness in traditional fishing societies, and found that fishermen from individualistic societies are far more competitive than fishermen from collective societies, and the this difference is positively correlated with work experience. Maria Bigoni et al. (2013) found that there are large differences in cooperative behavior between the northern and southern regions of Italy, and suggested that the frequency of wars in history could explain these differences in norms.

Although culture is one of the main determinants of people's economic behaviors, cultural effects are notoriously difficult to quantitatively measure. Nevertheless, several studies show that culture influences experimental behavior modeled in the laboratory. Alvin E Roth et al. (1991) and Joseph Henrich, Robert Boyd, Samuel Bowles, Colin Camerer, Ernst Fehr, Herbert Gintis and Richard McElreath (2001) found that behavior in the ultimatum game differs across cultures. Uri Gneezy et al. (2009) carried out seminal field experiments in African and Indian societies, and demonstrated that culture shapes people's competitive behavior in experimental tasks.

A new player in the field towards explaining the emergence of cooperative behavior in human society is the rice culture theory linking historical agricultural practices to cultural norms that become embedded in individual behavior. Malcolm Gladwell (2008) argued that the plantation of paddy rice might explain the wide difference in educational achievement between people from paddy rice areas and people from non-paddy rice areas. In their seminal study, T. Talhelm, X. Zhang, S. Oishi, C. Shimin, D. Duan, X. Lan and S. Kitayama (2014) provided the first quantitative evidence to support the notion that interdependent-independent cognitive styles are to some extent dependent on historical rice paddy farming.

While Jianqing Ruan et al. (2014) raised some doubts on Talhelm et al. (2014)'s paper. Our study departs from previous approaches by introducing laboratory based experimental economic tasks as well as by examining participants in a national representative sample in China to test whether subjects born in rice paddy regions of China are indeed characterized by greater prosocial norms.

Another relevant concept is that of social capital. Robert Putnam (1993) defined it as "features of social organization such as trust, norms and networks, that can improve the efficiency of society by facilitating coordinated actions". Social capital is one of the key concepts in social sciences, and is measured at both the individual (Edward L Glaeser et al., 2002, Dean S Karlan, 2005) and community levels (James Coleman, S, 1990, Robert D Putnam, 2000). Edward L Glaeser, David Laibson and Bruce Sacerdote (2002) advocated the application of methodology derived from experimental economics to measure social capital and found that subjects' past trust behavior predicts people's behavior in the trust game. Dean S Karlan (2005) showed that people's behavior in the trust game predicts people's default rate at the level of microcredit economic interactions. The current study is related with social capital at the individual level, since we use experimental games as the main measure for each individual's prosocial behavior. Our research will contribute to a more complete picture of the differences in social capital across regions in China.

2.3 Results

2.3.1 Empirical strategy

To investigate the relationship between the rice farming ratio and people's cooperative behavior, we use both ordinary regression and instrumental variable regression. The following equation is our baseline specification,

$C_{i,p} = a + \beta Rice_p + \lambda X_{i,p} + \eta W_p + \varepsilon_{i,p}$,

where $C_{i,p}$ is the measurement of cooperation, $Rice_p$ is the proportion of rice farming at the province level, $X_{i,p}$ is the individual control variables including gender and family income, W_p is the province level control variables such as GPD per capita in 2010.

The instrumental variable regression tries to solve the possible endogeneity problem such as measurement error and reverse causality. The rice theory uses the rice cultivation data in 1996, the oldest available data from China Statistical Yearbook, as a measure of agricultural differences across China. This is not the perfect measure of historical rice farming ratio that influences the local culture, and measurement error may occur.

Based on the United Nations Food and Agriculture Organization's Global Agro-ecological Zones database, T. Talhelm, X. Zhang, S. Oishi, C. Shimin, D. Duan, X. Lan and S. Kitayama (2014) chose a score called rice suitability as the instrument for the rice farming. It is a score of the environmental suitability for growing wetland rice. The United Nations uses multiple dimensions of geographic information from temperature, humidity, evaporation, soil quality, and slope to compute the score. Our later results will show that it is not a weak instrument. Many researchers (Alberto Alesina, Nathan Nunn and Paola Giuliano, 2013, Francesco Amodio and Giorgio Chiovelli, 2013, Oeindrila Dube et al., 2013, Jacob Hochard and Edward Barbier, 2014) have used this database to run instrumental variable regressions to handle the possible endogeneity problem associated with the agricultural production.

Some people worry that these environmental conditions may not impact people's cooperative behavior through the production of rice. For example, low temperature may prompt people to stay more in their own houses and have less social interaction. Our subsequent results show that some regions with high temperature will have less social interaction.

With additional consideration of the prior results on independent and interdependent thinking style, the direction of our results using several data sets is consistent with each other. It is difficult to rationalize all the results only using information of temperature rather than the rice culture theory.

2.3.2 Evidence from Incentivized Experimental Games

(I) Experimental Tasks

In 2010 and 2012, we ran two waves of experimental studies in Beijing. With a total of 1043 university student subjects from different provinces of China, we study people's prosocial behavior with one-short experimental tasks including public goods game, trust game, modified dictator game, and some other games. All the tasks are incentivized – we randomly choose one of these social games to implement it, and pay the cash according to their decisions[5]. These measures are based on the real behavior of the subjects, and they are better instrument compared with the simple questionnaire especially in the prosocial area. In addition, we collected demographic information through questionnaires including their birthplace. The Appendix A shows the experimental instructions.

Our approach has several advantages on studying this problem. Firstly, for cooperative behavior, we collected the behavioral data, rather than self-report or non-incentivized tasks. Secondly, although students from different provinces may have different cultural backgrounds, they are in the same environment – Beijing; this makes our test environment less noisy. Thirdly, the rich experimental games enable us to dig deep into true motivation under different prosocial situations.

The following games are directly related with cooperative behavior. The public goods game (PG) is widely used in the experimental economics. In our study, each subject participates in a public goods game with another anonymous players. For the endowment of RMB 80 Yuan, the subject allocates it between a common pool and his own pocket. The return rate of the common pool is 1.6. After the two players make their decisions, the amount in the pool will be distributed equally to both

[5] Although we didn't randomize the order of experimental tasks, we don't think it will cause serious measurement error. The first reason is that our subjects received no feedback on their decisions in each task; the second is that the average behavior in our games is generally consistent with those in the existing literature.

players. If there is no other-regarding preference, the optimal strategy for the subject is to invest nothing in the common pool. While if people take cooperative behavior and put money in the common pool, the money contributed is used as a measure of cooperation.

One famous experimental task measuring trust behavior is the trust game (TG). In the experiment, Person A is endowed with 80 Yuan, and makes the decision to send some amount of money to Person B. The money sent to Person B will be tripled; in turn Person B will decide the amount of money sent back to Person A. Usually researchers use the amount that Person A send out as a measure of trust behavior, while use the amount that Person B send back as a measure of trustworthiness. In our study, we adopt the strategy method to get people's decision as both Person A and Person B[6].

We also employed the modified dictator game developed by James Andreoni and John Miller (2002). This game contains 5 dictator games, and varies the endowments and the relative prices of giving from

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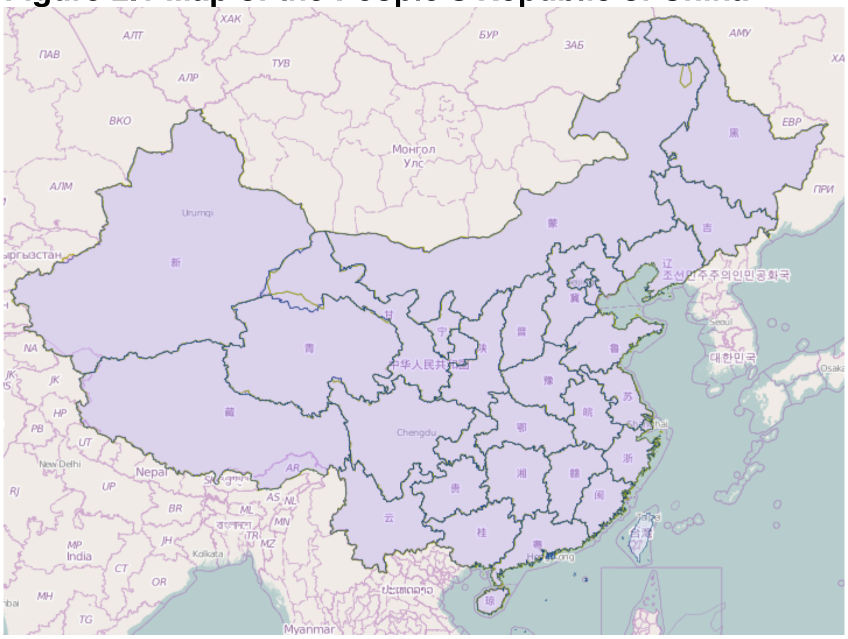
[6] This approach may bias upward the amount of trust and trustworthiness seen in the experiment. In our sample, the average trusting amount is around 60% of the endowment and the return rate is 115%, which are within the usual range of 40%-60% trusting and 110% average repayments in the literature. In addition, our research focus is how the rice farming ratio influence the additional amount of trusting, hence the level of trusting is not important. The Appendix A shows the original instructions.

1/3 to 3. This game provides useful information on people's altruistic preferences under different situations.

Results

Figure 2.1 depicts a map of the People's Republic of China, and Table 2.1 shows the distribution of subjects in each province covered in our sample. All the provinces except Tibet are covered in our sample. The subjects are distributed relatively equally across the whole China, and there is no single province that contributes more than 10% of the total sample. To be consistent with the analysis of T. Talhelm, X. Zhang, S. Oishi, C. Shimin, D. Duan, X. Lan and S. Kitayama (2014),we also excluded the subjects from Inner Mongolia and Xinjiang, considering their large group of non-Han ethnic peoples and a strong herding culture.

Figure 2.1 Map of the People's Republic of China



Notes: The central shadow area is the People's Republic of China, with each province being separated by lines.

Table 2.1 Sample Distribution across Provinces

Province	N	Percent	Province	N	Percent
Anhui	37	3.46	Jiangsu	37	3.46
Beijing	31	2.9	Jiangxi	69	6.45
Chongqing	11	1.03	Jilin	41	3.84
Fujian	33	3.09	Liaoning	6	0.56
Gansu	37	3.46	Ningxia	19	1.78
Guangdong	27	2.53	Qinghai	6	0.56
Guangxi	22	2.06	Shaanxi	49	4.58
Guizhou	15	1.4	Shandong	101	9.45
Hainan	10	0.94	Shanghai	7	0.65
Hebei	67	6.27	Shanxi	50	4.68
Heilongjiang	45	4.21	Sichuan	53	4.96
Henan	99	9.26	Tianjin	23	2.15
Hubei	43	4.02	Xinjiang	21	1.96
Hunan	38	3.55	Yunnan	22	2.06
Inner Mongolia	20	1.87	Zhejiang	30	2.81

Table 2.2 provides the descriptive statistics of the main variables.

Notice that the average contribution in the public goods game is around 50

Yuan, which is more than half of the endowment 80 Yuan. This pattern is a clear rejection of the prediction of Nash equilibrium with pure selfish motivation. Table 2.3 shows the average public goods contributions of each province in the ascending order - there is a lot of heterogeneity across provinces.

Table 2.2 Summary Statistics

Variables	Mean	Standard error	Min	Max	Observations
Contribution in PG	49.7174	26.7462	0	80	1043
Sex	.5064	.5002	0	1	1041
Income	6.0246	6.3220	0	72	986
Percent of paddy	.3144	.3157	0	.88	1022
Rice suitability index	26.6905	23.8468	0	56.2	1022
GDP 2010	3.1832	1.4254	1.3119	7.6074	1022

Notes: Sex is a dummy variable for which 1 means female and 0 means male. Income and GDP 2010 numbers are reported in units of 10,000 RMB.

Table 2.3 Average Contributions in the Public Goods Game

Province	N	Contribution	Province	N	Contribution
Shanghai	7	32.8572	Chongqing	11	51.3636
Heilongjiang	45	34.3333	Beijing	31	51.9032
Gansu	37	39.1792	Shanxi	50	52.3876
Jilin	41	41.5	Ningxia	19	52.6316
Fujian	33	43.394	Anhui	37	53.054
Tianjin	23	44.1304	Guangxi	22	53.7272
Hebei	67	46.0448	Qinghai	6	54.5
Jiangsu	37	47.5948	Jiangxi	69	54.7392
Liaoning	6	47.6668	Hunan	38	54.8684
Guizhou	15	48.4668	Zhejiang	30	55
Guangdong	27	48.5184	Shaanxi	49	56.9148
Sichuan	53	49.9624	Hubei	43	56.9308
Henan	99	50.6272	Yunnan	22	59.8636
Shandong	101	51.1088	Hainan	10	60

Public Goods Game

Table 2.4 shows the ordinary least squares regression (OLS) and instrumental regression (IV) results of the public goods game. In OLS regressions, the contribution amount in the public goods game is positively correlated with the percent of paddy rice farming area relative to the total plantation area in the province, with or without control variables including gender, family income, province GDP per capita in 2010, and the study wave dummy variable etc.; the coefficient is around 5, which means that if subject is born in a province which has 100% paddy rice will contribute 5 Yuan more than those who is born in a province with no paddy rice farming. In the instrumental regressions, the paddy rice ratio becomes significant at the 0.05 statistical level; the coefficients increase to around 10, which suggests a bigger impact of rice culture. In addition, we notice that the male subjects tend to contribute more than the female subjects. For the family income and province level GDP per capita, both of them are negative; this suggests that in our student sample, higher income level tends to let them contribute less in the public goods game. Appendix A shows the original instructions. Appendix B shows the first-stage results of the instrumental regression.

Table 2.4 OLS and IV Estimates of The Public Goods Game

	(1) OLS	(2) OLS	(3) IV	(4) IV
VARIABLES	Contribution	Contribution	Contribution	Contribution
Percent of	4.983	5.517*	10.60**	10.10**
paddy	(3.271)	(3.145)	(4.844)	(4.875)
Sex		-3.084*		-3.099**
		(1.528)		(1.458)
Income		-3.415*		-3.542*
		(1.912)		(1.862)
GDP 2010		-0.225		-0.212
		(0.660)		(0.722)
Wave 2010		-0.597		-0.582
		(1.638)		(1.623)
Constant	48.34***	52.23***	46.57***	50.82***
	(1.791)	(3.331)	(2.232)	(3.739)
Observations	1,022	965	1,022	965
F-stat			1475.1	413.15
R-squared	0.003	0.012		0.009

Notes: Standard errors in parentheses clustered at the province level[7]. * significant at 10%; ** significant at 5%; *** significant at 1%. Sex is a dummy variable for which 1 means female and 0 means male. Income and GDP 2010 numbers are reported in units of 10,000 RMB. Wave 2010 is a dummy variable for which 1 means the 2010 study and 0 means the 2012 study. F-stat is the F statistic of the first stage result in the instrumental regression.

Trust Game

Trust is another behavior closely related with cooperation. The results from the trust game in Table 2.5 are similar with those in the public goods game. In OLS regression, the rice ratio in each province is positively correlated with the trust behavior. In instrumental variable regressions, the ratio becomes statistically significant at 5% level. The magnitude of rice ratio is similar. There is a noticeable gender effect:

[7] We also checked the bootstrapping standard error at the province level, and all the results remain robust.

males tend to trust more. However, for the trustworthiness behavior of the trustee, we have not found that the rice ratio has an effect[8].

Table 2.5 The Trust Game

	(1) OLS	(2) OLS	(3) IV	(4) IV
VARIABLES	Trust in TG	Trust in TG	Trust in TG	Trust in TG
Percent of paddy	3.549	3.822*	8.241*	6.754**
	(2.337)	(2.003)	(4.314)	(3.427)
Sex		-9.006***		-9.013***
		(1.541)		(1.504)
Income		-0.159		-0.166
		(0.112)		(0.109)
GDP 2010		-0.667		-0.659
		(0.410)		(0.427)
Wave 2010		3.769**		3.779***
		(1.368)		(1.352)
Constant	47.24***	53.09***	45.77***	52.19***
	(1.458)	(2.430)	(1.882)	(2.541)
Observations	1,020	962	1,020	962
F-stat			1458.28	407.64
R-squared	0.002	0.053		0.052

Notes: Standard errors in parentheses clustered at the province level. * significant at 10%; ** significant at 5%; *** significant at 1%. Sex is a dummy variable for which 1 means female and 0 means male. Income and GDP 2010 numbers are reported in units of 10,000 RMB. Wave 2010 is a dummy variable for which 1 means the 2010 study and 0 means the 2012 study. F-stat is the F statistic of the first stage result in the instrumental regression.

People's contribution in the public goods game and the trust behavior in the trust game are not due to solely social preference, and risk may play a role if people have reciprocity motivation. In order to determine whether risk attitude rather than social preference is the driving force of our previous results, we add a risk attitude measure. The risk attitude measure is the subject's switching point in his choice between a lottery

[8] We use the slope and intercept of the regression from trustee's return amount on his received amount as the measure of trustworthiness, and this measure is not significantly correlated with the rice farming ratio. The Appendix C shows the results.

and some certain amount of money. Appendix A shows the instructions for this task. Table 2.6 shows that our main results still hold: a higher paddy rice farming ratio signifies that people are more prosocial in the two games, and the magnitude is similar to those in Table 2.4 and Table 2.5. The risk measure is statistically significant at the 0.1 level in the trust game, but not significant in the public goods game. The coefficients are all positive in both games: if people are more risk taking, they tend to cooperate more or trust more. It suggests that, although risk attitude plays a role in people's cooperative behavior, it is not the driving force.

Table 2.6 Controlling for Risk Attitude

	(1)	(2)	(3)	(4)
	OLS	OLS	IV	IV
VARIABLES	Contribution in PG	Trust in TG	Contribution in PG	Trust in TG
Percent of paddy	5.331	3.032	10.51**	5.559
	(3.375)	(2.124)	(5.139)	(3.627)
Risk	0.354	1.036*	0.282	1.001*
	(0.461)	(0.528)	(0.456)	(0.535)
Sex	-3.143*	-8.768***	-3.177**	-8.782***
	(1.684)	(1.579)	(1.607)	(1.527)
Income	-0.268	-0.107	-0.281*	-0.113
	(0.168)	(0.121)	(0.164)	(0.117)
GDP 2010	-0.344	-0.900*	-0.329	-0.894*
	(0.678)	(0.454)	(0.737)	(0.482)
Wave 2010	-1.578	3.309**	-1.500	3.348**
	(1.889)	(1.585)	(1.890)	(1.561)
Constant	50.93***	49.01***	49.69***	48.40***
	(4.688)	(3.804)	(4.922)	(3.810)
Observations	851	848	851	848
F-stat			304.37	299.54
R-squared	0.013	0.063	0.010	0.062

Notes: Standard errors in parentheses clustered at the province level. * significant at 10%; ** significant at 5%; *** significant at 1%. Sex is a dummy variable for which 1 means female and 0 means male. Income and GDP 2010 numbers are reported in units of 10,000 RMB. Wave 2010 is a dummy variable for which 1 means the 2010 study and 0 means the 2012 study. Risk is a measure of risk attitude in an experimental lottery choice task ranging from 0 to 10; a higher the number means the subject is more risk loving. F-stat is the F statistic of the first stage result in the instrumental regression.

Modified Dictator Game

Is rice farming's influence on cooperative behavior mainly driven by altruism? The results in our modified dictator game suggest it is not the case. The design of the modified dictator game comes from Andreoni and Miller (2002). Appendix A shows the detailed instructions. All the dependent variables in Table 2.7 are the amount of money sent out by the subjects in the dictator game. Equations (1) to (5) corresponds to the five efficiency ratios of the money sent out to the other party. For example, in Equation (1) of Table 2.7, the efficiency ratio is 2, and it means that if the subject sends out 1 dollar, the other subject will receive 2 dollar. For Equations (1) and (2), the coefficients of rice farming ratio are both positive but statistically insignificant; this direction is consistent with those in the PG and TG. For Equations (3) to (5), the coefficients of rice farming ratio become even negative. Notice that when the efficiency ratio becomes 1/2 or 1/3, the action of altruism is inefficient. Overall the results here suggest that people come from provinces with a higher rice farming ratio tend to be less altruistic in the inefficient occasions. We could understand this result with another perspective – in these inefficient cases, higher rice farming ratio tend to let people choose the actions that maximize the sum of the two players, since keep the money in your own hand is efficient.

Table 2.7 IV Estimates of the Modified Dictator Game

VARIABLES	(1) R=2 Giving	(2) R=3 Giving	(3) R=1/2 Giving	(4) R=1/3 Giving	(5) R=1 Giving
Percent of	3.480	4.259	-9.865**	-20.35**	-1.255
paddy	(6.083)	(3.609)	(4.920)	(8.167)	(2.466)
Sex	-11.97***	-6.643***	6.698**	8.872	-0.340
	(2.146)	(1.329)	(3.365)	(5.773)	(2.067)
Wave 2010	8.643***	5.651***	-2.553	-0.655	-0.874
	(3.212)	(2.148)	(2.125)	(3.563)	(2.123)
Income	-0.454*	-0.194	-0.257	-0.576	-0.345**
	(0.245)	(0.174)	(0.218)	(0.351)	(0.143)
GDP 2010	-0.469	-0.691	-1.461	-0.445	-0.218
	(1.098)	(0.571)	(1.050)	(1.947)	(0.327)
Constant	66.96***	35.03***	48.91***	69.39***	40.58***
	(3.310)	(1.941)	(3.761)	(6.164)	(2.130)
Observations	967	966	966	968	969
F-stat	411.86	411.68	408.15	412.39	413.99
R-squared	0.040	0.041	0.015	0.010	0.008

Notes: Standard errors in parentheses clustered at the province level. * significant at 10%; ** significant at 5%; *** significant at 1%. Sex is a dummy variable for which 1 means female and 0 means male. Income and GDP 2010 numbers are reported in units of 10,000 RMB. Wave 2010 is a dummy variable for which 1 means the 2010 study and 0 means the 2012 study. All the coefficients come from instrument variable regressions. F-stat is the F statistic of the first stage result in the instrumental regression.

Sequential Prisoner's Dilemma Game

Is rice farming's influence on cooperative behavior mainly driven by the inequality aversion motivation? The results in a sequential game suggest it is not the case. Figure 2.2 illustrates the sequential game: Person A moves first with the choice of Left or Right, then Person B chooses Left or Right with the knowledge of Person A's action, which leads to the final outcomes. Notice that when Person A chooses Left, Person B's action of choosing Left will lead to the outcome of ($120, $120) – it is both efficient and equal compared with the alternative choice Right; when Person A chooses Right, Person B's action of choosing Left will lead to outcome ($140, $60) – it is efficient but not equal compared with the Right choice. Although we use the strategy method, intention may matters here. Maybe Person B think Person A's choice of Left means good intention, hence tends to choose Left to reward Person A; similarly Person B may think Person A's choice of Right means bad intention, hence tends to choose Right to punish Person A. For Person B's choice, the directions of positive reciprocity and negative reciprocity options are the same as the more efficient ones.

Outlined in Table 2.8 are the results on the linear probability regression on Player B's choice, should Player A chooses Left. In the four regressions, the general message is that a higher ratio of rice farming translates into a higher probability that people will prefer the ($120, $120) outcome to the ($60, $140) one. This result is consistent with people's behavior in the public goods game and the trust game. Outlined in Table 2.9 are the results on the linear probability regression on Player B's choice, should Player A chooses Right. Here a higher ratio of rice farming translates into a higher probability that people will prefer ($140, $60) outcome to ($68, $68) one. This result is in the same direction as people's behavior in the inefficient dictator game. In other words, people from higher rice farming ratio areas seem to be more averse to inequality or more positive reciprocal in the efficiency-enhancing situations, but not in the inefficient case.

Figure 2.2 The Sequential Game

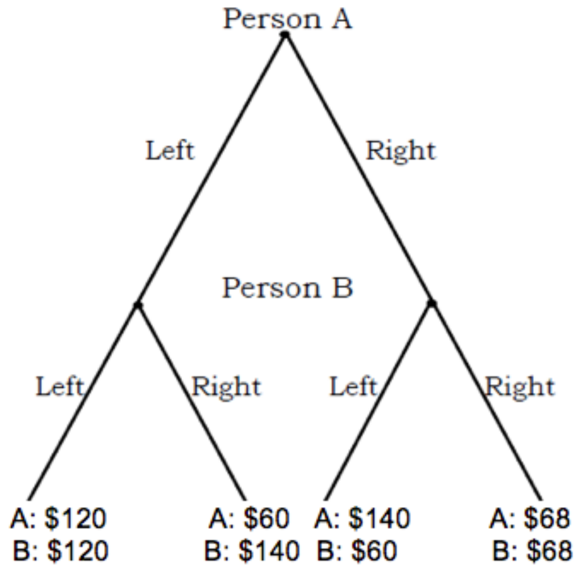


Table 2.8 Person B's Choice of Left in the Sequential Game

	(1) OLS	(2) OLS	(3) IV	(4) IV
VARIABLES	Left Choice	Left Choice	Left Choice	Left Choice
Percent of paddy	0.0714 (0.0546)	0.0903 (0.0584)	0.149* (0.0764)	0.150** (0.0724)
Sex		-0.0632* (0.0336)		-0.0635** (0.0322)
Income		-0.00619** (0.00271)		-0.00634** (0.00262)
GDP 2010		-0.00370 (0.00786)		-0.00352 (0.00811)
Wave 2010		0.0133 (0.0325)		0.0133 (0.0319)
Constant	0.595*** (0.0196)	0.665*** (0.0445)	0.571*** (0.0235)	0.647*** (0.0449)
Observations	1,025	967	1,025	967
F-stat			1477.84	412.13
R-squared	0.002	0.015		0.013

Notes: Standard errors in parentheses clustered at the province level. * significant at 10%; ** significant at 5%; *** significant at 1%. The dependent variable Left Choice is a dummy variable for which 0 means Right and 1 means Left. Sex is a dummy variable for which 1 means female and 0 means male. Income and GDP 2010 numbers are reported in units of 10,000 RMB. Wave 2010 is a dummy variable for which 1 means the 2010 study and 0 means the 2012 study. F-stat is the F statistic of the first stage result in the instrumental regression.

Table 2.9 Person B's Choice of Right in the Sequential Game

VARIABLES	(1) OLS Right Choice	(2) OLS Right Choice	(3) IV Right Choice	(4) IV Right Choice
Percent of	0.157***	0.135***	0.218***	0.148***
paddy	(0.0470)	(0.0429)	(0.0617)	(0.0533)
sex		-0.0320		-0.0320
		(0.0215)		(0.0210)
Income		-0.00137		-0.00140
		(0.00246)		(0.00241)
GDP 2010		-0.0239**		-0.0238**
		(0.0105)		(0.0103)
Wave 2010		0.0199		0.0199
		(0.0266)		(0.0262)
Constant	0.339***	0.436***	0.320***	0.431***
	(0.0215)	(0.0430)	(0.0284)	(0.0479)
Observations	1,018	961	1,018	961
F-stat			1451.46	409.90
R-squared	0.010	0.015	0.009	0.015

Notes: Standard errors in parentheses clustered at the province level. * significant at 10%; ** significant at 5%; *** significant at 1%. The dependent variable Right Choice is a dummy variable for which 0 means Right and 1 means Left. Sex is a dummy variable for which 1 means female and 0 means male. Income and GDP 2010 numbers are reported in units of 10,000 RMB. Wave 2010 is a dummy variable for which 1 means the 2010 study and 0 means the 2012 study. F-stat is the F statistic of the first stage result in the instrumental regression.

Overall we find strong support for the rice theory on people's cooperative behavior in the public goods game. Additional results from the trust game, the risk task, the modified dictator game, and the sequential game help us narrow down the possible explanations on how the rice farming ratio influences people's cooperative behavior – risk taking, altruism, and inequality aversion may not be the driving forces. These results suggest that efficiency motivation is the key, and reciprocity motivation may also plays a role.

2.3.3 Evidence from China Family Panel Studies Data

There are several concerns in our above empirical results. The first is that the subjects are all college students, and they may have different behavior from ordinary people. Another concern that our sample is not a representative sample of the entire China, and it is difficult to generalize the conclusions to the national level. The third is that this data only provide a preference-based measure of cooperative behavior, and more broad measures are necessary to understand the robustness of the preference-based measurement.

The China Family Panel Studies (CFPS) is a large national representative panel survey data in China. It collects individual, family, and community level data in 25 provinces, and has broad information on China's society, economy, demography, education, and health etc. The CFPS 2010 wave is its first wave data, and there are more than 50,000 individual observations. We use both individual and community level data to study how rice culture influence people's cooperative behavior. For better comparison with previous results from experimental games, all the measures used are based on people's behavior rather than attitudes.

Our previous results show that the cooperative behavior in the public goods game may be due to reciprocity motivation. The following two questions in CFPS provide measurement on reciprocity: "Have you ever received help from others?" and "Have you ever provided help to others?" Column (1) and Column (2) in Table 2.10 are both OLS estimation results, and we find that the coefficients of paddy rice ratio are positive but not statistically significant. With regard to the instrumental regressions of Column (3) to Column (4), the coefficients of paddy rice ratio suggest a large effect: when the paddy rice ratio increases by 1 percent, the probability of get help or give help will increase by around 0.1 percent; both of them are significant at 5% level.

Table 2.10 Get and Give Help

	(1)	(2)	(3)	(4)
	OLS	OLS	IV	IV
VARIABLES	Get help	Give help	Get help	Give help
Percent of paddy	0.0573	0.0609	0.109**	0.0978**
	(0.0491)	(0.0512)	(0.0502)	(0.0456)
Sex	-0.0781***	-0.0711***	-0.0783***	-0.0713***
	(0.00861)	(0.00832)	(0.00826)	(0.00780)
Personal income	0.00653*	0.0343***	0.00599**	0.0339***
	(0.00321)	(0.00507)	(0.00243)	(0.00478)
Family income	0.0000595	0.00222**	-0.0000656	0.00213**
	(0.000757)	(0.000957)	(0.000737)	(0.000955)
Expenditure	0.00138*	0.000710	0.00135*	0.000689
	(0.000726)	(0.000768)	(0.000704)	(0.000795)
Urban	-0.0320	-0.0106	-0.0329	-0.0112
	(0.0236)	(0.0176)	(0.0232)	(0.0199)
GDP 2010	-0.0247*	-0.0142	-0.0271***	-0.0159**
	(0.0129)	(0.0108)	(0.00854)	(0.00781)
Constant	0.546***	0.327***	0.539***	0.321***
	(0.0461)	(0.0400)	(0.0365)	(0.0337)
Observations	26,889	26,883	26,889	26,883
F-stat			28.47	28.55
R-squared	0.014	0.038	0.013	0.037

Notes: Standard errors in parentheses clustered at the province level. * significant at 10%; ** significant at 5%; *** significant at 1%. Sex is a dummy variable for which 1 means female and 0 means male. Personal income, Family income, Expenditure, GDP 2010 numbers are reported in units of 10,000 RMB. Urban is dummy variable in which 1 means urban Hukou status and 0 means rural Hukou status. Family member 1 means the number of core family members, and Family member 2 means the number of other family members. Here we only use the Han Chinese sample, and the unit of observation is individual. F-stat is the F statistic of the first stage result in the instrumental regression.

In daily life, cooperative behavior involves social interaction, the behavioral measure of which is encapsulated in the following two questions on frequency: “Last month, do you have any social interactions with your neighbors?” and “Last month, do you have any social interactions with your relatives?” Table 2.11 indicates the results of linear probability estimation of social interaction. The dependent variables are dummy variables on whether the person has any social interaction with the neighbors or relatives. Column (1) and (2) are OLS estimation, and we noticed that the paddy rice planation ratio has a moderate and statistical significant effect on social interaction: 1 percent increase of rice farming ratio will increase the probability of interacting with the neighbor by around 0.1 percent. Column (3) and (4) illustrate that this pattern still holds when we use rice suitability index as the instrument for paddy rice farming.

Table 2.11 Social Interaction

	(1)	(2)	(3)	(4)
	OLS	OLS	IV	IV
VARIABLES	Neighbor interaction	Relative interaction	Neighbor interaction	Relative interaction
Percent of	0.105**	0.0884**	0.103**	0.117**
paddy	(0.0391)	(0.0370)	(0.0430)	(0.0479)
Family income	0.000984	0.00266	0.000989	0.00262
	(0.000648)	(0.00179)	(0.000639)	(0.00173)
Expenditure	0.000467**	0.00124**	0.000468**	0.00123**
	(0.000218)	(0.000578)	(0.000212)	(0.000565)
Urban	-0.0457	0.103***	-0.0457	0.103***
	(0.0328)	(0.0248)	(0.0320)	(0.0244)
GDP 2010	0.00528	0.0117	0.00533	0.0109
	(0.0138)	(0.0112)	(0.0136)	(0.0114)
Core family		0.0201***		0.0193***
member		(0.00415)		(0.00411)
Other family		-0.00975***		-0.00974***
member		(0.00335)		(0.00333)
Constant	0.702***	0.480***	0.703***	0.476***
	(0.0581)	(0.0553)	(0.0559)	(0.0545)
Observations	13,555	13,550	13,555	13,550
F-stat			30.95	22.34
R-squared	0.009	0.029	0.009	0.029

Notes: Standard errors in parentheses clustered at the province level. * significant at 10%; ** significant at 5%; *** significant at 1%. Family income, Expenditure, and GDP 2010 numbers are reported in units of 10,000 RMB. Urban is a dummy variable for which 1 means urban Hukou status and 0 means rural Hukou status. Core family member means the number of core family members, and Other family member means the number of other family members. Here we only use the Han Chinese sample, and the unit of observation is family. F-stat is the F statistic of the first stage result in the instrumental regression.

The China Family Panel Studies (CFPS) also provides community level data, which enable us to determine whether the rice culture influences public goods provision at the community level. In the questionnaire, one question inquires into the allocation of resources by a village in the preceding year. There are 7 categories: (1) village administration fee, (2) the money distributed to the villagers, (3) the money on public services (road, water, electricity etc.), (4) the money on education, (5) the investment on production (agriculture, irrigation etc.), (5) the investment on the collective enterprises, (6) the investment on the collective enterprises, and (7) other expenditures except the above ones. The third category is directly related to the provision of public goods. In China, at the village level, most of the communities could select their village committee through direct voting. Accordingly, these decisions on village expenditure may reflect ordinary people's willingness. We checked whether the rice culture would have an impact on the provision of community public goods.

The estimation results in Table 2.12 lend some support to our previous finding using the college student sample. From Column (3), the coefficient of paddy rice ratio is 557.9 and marginal significant (p value is 0.065), which implies that 1 percent of rice ratio increase will lead to 55.79 thousand RMB more spending in public service. Notice that we don't find statistically significant impact on other categories of expenditure. Since public service expenditure is a measure of public goods, we take the results as support of the rice theory.

Table 2.12 Village Expenditure

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
VARIABLES	Admin	Distribution	Service	Education	Production	Economy	Others
Percent of	312.2	-21.33	557.9*	317.5	90.49	255.8	255.8
paddy	(234.0)	(29.61)	(302.0)	(202.3)	(163.3)	(184.1)	(184.1)
Financial	1,178***	12.23***	1,115***	529.0***	65.51	121.5	121.5
income	(394.3)	(4.531)	(400.5)	(192.3)	(49.30)	(114.5)	(114.5)
Population	-0.00672	0.0170**	-0.0129	-0.0129	-0.00316	0.00523	0.00523
	(0.0124)	(0.00854)	(0.0191)	(0.0169)	(0.00991)	(0.0113)	(0.0113)
Income per	-222.5**	69.50***	-264.4**	-121.3	8.043	-93.45	-93.45
capita	(106.1)	(24.27)	(110.6)	(98.73)	(74.09)	(95.57)	(95.57)
Urban	-117.2	7.185	-123.2*	-51.92	12.82	-98.96*	-98.96*
	(117.2)	(7.525)	(63.19)	(77.92)	(128.5)	(53.51)	(53.51)
Constant	200.4***	-42.00**	101.1**	53.75	53.12	32.09	32.09
	(53.01)	(16.98)	(48.75)	(45.55)	(35.40)	(29.78)	(29.78)
Observations	322	332	330	330	330	332	332
F-stat	35.22	34.03	32.39	32.55	32.37	34.67	34.67
R-squared	0.159	0.196	0.251	0.120	0.002	0.025	0.025

Notes: Standard errors in parentheses clustered at the province level. * significant at 10%; ** significant at 5%; *** significant at 1%. Financial income and Income per capita numbers are reported in units of 10,000 RMB. Urban is a dummy variable for which 1 means urban Hukou status and 0 means rural Hukou status. Here we use only the Han Chinese sample. F-stat is the F statistic of the first stage result in the instrumental regression.

If rice culture influences public goods provision in local communities, it may also influence the economic growth rate. As a rough test, we use the ratio of province level GPD per capita of 2010 over GDP capita of 1978 as a measurement of economic growth rate, and check its relationship with the ratio of rice farming in each province. Figure 2.3 shows that the economic growth rate is positively correlated with rice farming ratio. Table 2.13 demonstrates more results using both regression and instrumental variable regression. The direction is consistent with the rice culture theory – high rice farming tends to let the local people have higher social capital, hence higher economic growth rate. This rules out one alternative hypothesis - the economic growth will reduce the proportion of agricultural land area and especially the main crop's farming area, which means that higher economic growth rate will leads to lower rice farming ratio.

Figure 2.3 Economic Growth Rate Correlates with Rice Farming Ratio

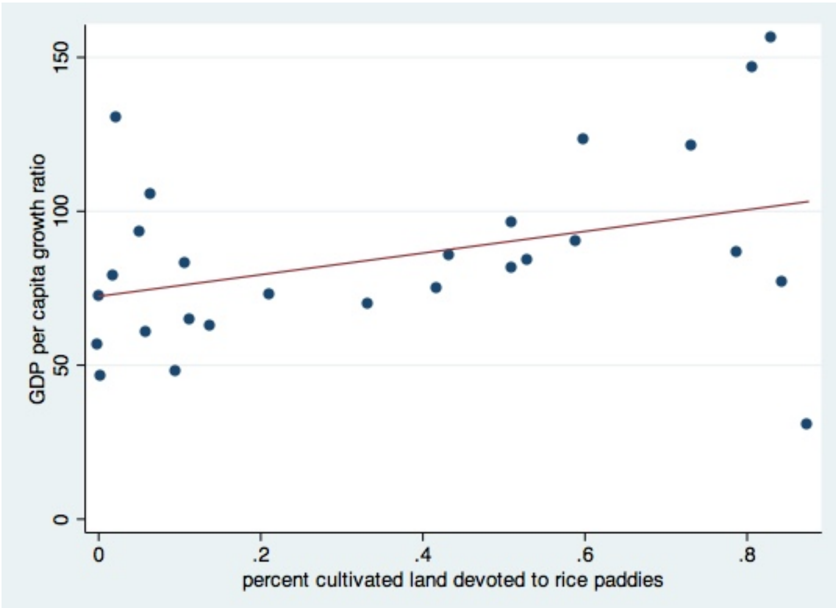


Table 2.13 Economic Growth and Rice Farming

	(1) OLS	(2) IV
VARIABLES	Growth rate	Growth rate
Percent of paddy	39.92**	42.86**
	(17.99)	(16.96)
GDP 1978	-0.0328***	-0.0330***
	(0.00587)	(0.00582)
Constant	86.37***	85.41***
	(7.492)	(7.436)
Observations	27	27
F-stat		35.41
R-squared	0.405	0.405

Notes: Robust standard errors in parentheses. ** significant at 5%; *** significant at 1%. GDP 1978 per capita numbers are reported in units of RMB. Here we use the province level data. F-stat is the F statistic of the first stage result in the instrumental regression.

2.3.4 Discussion

When we put everything together, the overall evidence suggests that the rice culture will make people more cooperative. The experimental games provide incentivized measures of cooperative behavior, while the students sample is relative homogeneous. These give us good internal validity. The CFPS data has a national representative sample as well as more broad measure of prosocial behavior, which adds external validity to the previous results.

However, apart from the rice theory, there are several alternative hypotheses.

Alternative Hypothesis 1: modernization hypothesis. Joseph Henrich, Robert Boyd, Samuel Bowles, Colin Camerer, Ernst Fehr, Herbert Gintis and Richard McElreath (2001) pointed out the prosocial behavior in the 15 cultures across world is negatively correlated with the market integration index. This suggests that, in the modernization process people may become more self-interested over time.

To test this hypothesis, alternative measures of modernization have to be studied. One straightforward measure of modernization is GDP per capita. Since in our above regressions we have controlled for the GDP per capita, this is not the driving force of our rice culture theory results. In addition, we check three other measures of modernization to the control variables (T. Talhelm, X. Zhang, S. Oishi, C. Shimin, D. Duan, X. Lan and

S. Kitayama, 2014).The first one is the percentage of Internet penetration per province in 2007 from the China Internet Network Information Center, since some think that it is an indicator of the extent to which modern technology influences people's life. The second measure is the percentage of labor force employed in the private industry in 1996, since many think that China's modernization process is a transition from a state-owned or collective-owned economy to a private economy. The third measure is the percentage of GDP in industry and service in 2010, since modernization level is closely associated with industrialization process. The results as outlined in Table 2.14, however, show that no measure is an effective predictor of cooperative behavior in the OLS regression.

Table 2.14 Modernization Hypothesis

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Contribution in PG	Trust in TG	Contribution in PG	Trust in TG	Contribution in TG	Trust in TG
Internet penetration	4.055	0.736				
	(14.00)	(13.06)				
Private firm employment			-40.79	51.84		
			(103.9)	(50.38)		
Industry ratio					0.0332	0.0749
					(0.330)	(0.202)
Sex	-3.083*	-8.999***	-2.970*	-9.048***	-3.533**	-9.033***
	(1.593)	(1.561)	(1.585)	(1.590)	(1.595)	(1.520)
Income	-0.274*	-0.150	-0.272*	-0.134	-0.288*	-0.148
	(0.160)	(0.113)	(0.158)	(0.111)	(0.157)	(0.110)
GDP 2010	-0.457	-0.716	-0.0479	-0.920**	-0.337	-1.059
	(0.809)	(0.905)	(0.612)	(0.431)	(0.939)	(0.629)
Wave 2010	-0.597	3.758***	-0.742	3.736**	-1.034	3.529**
	(1.630)	(1.354)	(1.647)	(1.357)	(1.617)	(1.325)
Constant	54.01***	54.27***	54.04***	53.98***	51.25*	48.18***
	(3.059)	(2.345)	(3.197)	(2.265)	(27.17)	(16.84)
Observations	965	962	956	953	965	962
R-squared	0.008	0.051	0.008	0.050	0.008	0.051

Notes: Standard errors in parentheses clustered at the province level. * significant at 10%; ** significant at 5%; *** significant at 1%. Sex is a dummy variable for which 1 means female and 0 means male. Income and GDP 2010 numbers are reported in units of 10,000 RMB. Wave 2010 is a dummy variable for which 1 means the 2010 study and 0 means the 2012 study.

Alternative Hypothesis 2: the pathogen prevalence theory. Some studies (Corey L Fincher et al., 2008) point out that local culture could be influenced by the prevalence of infectious diseases – more infectious diseases will make people more suspicious of strangers, and hence more interdependent in local community. We test this hypothesis using the same data set of T. Talhelm, X. Zhang, S. Oishi, C. Shimin, D. Duan, X. Lan and S. Kitayama (2014). The following Table 2.15 shows the estimation results of pathogen prevalence theory where we only replace the rice farming variable with the death rate of infectious diseases. Since the infectious disease variables in all the equations are highly insignificant, we could easily reject this hypothesis. The general pattern of pathogen distribution in China confirms the above results: the southwest part of China has the highest proportion, while our prosocial behavior has the highest proportion at the south and central provinces.

Table 2.15 Death Rate of Infectious Diseases

	(1)	(2)
VARIABLES	Contribution in PG	Trust in TG
Death rate of infectious diseases	2.461	1.383
	(3.337)	(1.868)
Sex	-4.089**	-9.146***
	(1.611)	(1.765)
Income	-0.444***	-0.282***
	(0.132)	(0.0867)
GDP 2010	0.167	-0.632
	(0.991)	(0.547)
Wave 2010	-0.0352	4.445**
	(1.918)	(1.623)
Constant	54.19***	54.64***
	(3.759)	(2.852)
Observations	766	764
R-squared	0.021	0.067

Notes: Standard errors in parentheses clustered at the province level. * significant at 10%; ** significant at 5%; *** significant at 1%. Death rate of infectious diseases is a z score compile by T. Talhelm, X. Zhang, S. Oishi, C. Shimin, D. Duan, X. Lan and S. Kitayama (2014) which contains 21 provinces; the original data sets come from census data and a survey study (Junshi Chen et al., 1990). Sex is a dummy variable for which 1 means female and 0 means male. Income and GDP 2010 numbers are reported in units of 10,000 RMB. Wave 2010 is a dummy variable for which 1 means the 2010 study and 0 means the 2012 study.

Alternative Hypothesis 3: political control. Some think that if the region is closer to the political center Beijing, the government will have tighter ideology control, which will promote people's cooperative behavior through socialism education. To test this hypothesis, we use the distance between Beijing and the capital of the province as the proxy for the ideological control. The OLS regression results in Table 2.16 show that there is no effect of the distance to Beijing.

Table 2.16 Distance to Beijing

	(1)	(2)
VARIABLES	Contribution in PG	Trust in TG
Beijing distance	0.00108	0.000169
	(0.00134)	(0.00113)
Sex	-3.560**	-9.040***
	(1.590)	(1.526)
Income	-0.294*	-0.149
	(0.160)	(0.111)
GDP 2010	-0.0244	-0.619
	(0.726)	(0.443)
Wave 2010	-1.023	3.550**
	(1.620)	(1.330)
Constant	52.74***	53.93***
	(3.629)	(2.664)
Observations	984	981
R-squared	0.010	0.049

Notes: Standard errors in parentheses clustered at the province level. * significant at 10%; ** significant at 5%; *** significant at 1%. Beijing distance numbers are reported in units of kilometers. Sex is a dummy variable for which 1 means female and 0 means male. Income and GDP 2010 numbers are reported in units of 10,000 RMB. Wave 2010 is a dummy variable for which 1 means the 2010 study and 0 means the 2012 study.

From the above discussion, we have ruled out three possible alternative explanations to the rice culture theory. Although there may be some other explanations, we think the rice culture theory is the most plausible one, since it indeed confirms our daily intuition and the main predictions in previous literature.

2.4 Conclusions

Wide regional differences in cooperative behavior are observed in China. We have used a unique experimental economics data set to test the new theory of rice culture. In addition, we have used China Family Panel Studies (CFPS), a national survey data, to examine more broad measures related with cooperative behavior. The results from both data sets suggest that people from regions with a higher rice farming ratio tend to display more cooperative behavior. These results appear to confirm the rice culture theory.

The rice culture theory is a promising hypothesis that links people's living and working environmental conditions to their local cultures and real behaviors. It also offers a new perspective to understand how rice culture influences other behaviors such as risk taking and competitiveness. We will continue to explore this theory in future studies.

2.5 Appendix

2.5.1 Appendix A: Instructions for Behavioral Experiments

Modified Dictator Game

In this situation, **Person A** is endowed a fixed amount of money, and is asked what amount of money he/she wants to send to **Person B**. **Person B** makes no decision. The amount of money Person A sends to Person B will **be multiplied by a factor R.** That is, Person B will receive R dollars for every dollar sent by Person A. The amounts that Person A and Person B receive depend solely on how **Person A** decides to allocate the money.

Example 1 (Endowed with $50; factor **R = 2**): *Person A can either keep all $50, keep some and send the balance, or send all of $50 to an anonymous and randomly matched Person B. For every dollar sent by Person A, Person B will receive $2. If Person A keeps $50 and sends $0, Person B will receive $0 while Person A will keep $50. If Person A sends all $200, Person Person B will receive $200 x 2 = $400 while Person A will have $0.*

Example 2: (Endowed with **$120**; factor **R = 1/3**)*: Person A can send up to $120. Person B receives $1/3 for every dollar sent by Person A.*

Your decision as Person A: For each of the 5 cases below, please indicate the amount you would keep and the amount you would send. In each case, the sum of the amount of money you keep and the amount to be sent **must equal** your endowed amount as shown in the final column.

	Endowed Amount	Factor R	Amount Kept	Amount Sent	Total
1	$160	2			$160
2	$80	3			$80
3	$160	1/2			$160
4	$240	1/3			$240
5	$120	1			$120

Trust Game

Person A is endowed with $80 while Person B is endowed with no money. Person A has the option to send any part of $80 to **Person B**. The money Person A sends to person B is **tripled**; That is, for every $1 Person A sends, Person B receives $3. After receiving the tripled amount from Person A, Person B will have the option to send to Person A any part of the tripled amount received. The payoffs of Person A and Person B are given by:

Person A: $20 – Amount sent to Person B + Amount received from Person B

Person B: Tripled amount received from Person A – Amount sent to Person A

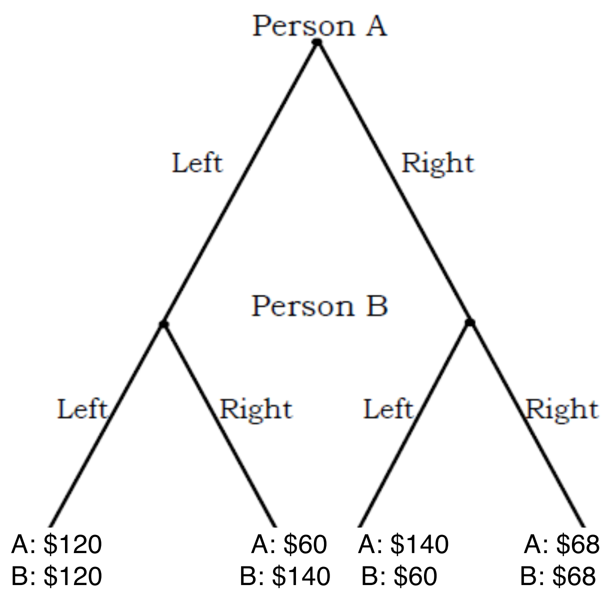
Your decision as Person A: Amount to be sent to Person B is $____ (*an integer between 0 and 20 inclusive*).

Your decision as Person B: For each possible sum of money which Person A might send to you, you would send the amount as indicated below to Person A.

Sent by A	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Tripled	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60
Send to A																				

Sequential Game

Person A can choose either LEFT or RIGHT as illustrated in the diagram below. **Contingent on each of Person A's 2 possible decisions – LEFT and RIGHT**, **Person B** can choose between LEFT and RIGHT. Together, the choices of Person A and Person B determine each person's payoff as shown. If both choose LEFT, they each receive $120. If both choose RIGHT, they each receive $68. If Person A chooses RIGHT and B chooses LEFT, the payoffs are $140 and $60 respectively. If Person A chooses LEFT and B chooses RIGHT, the payoffs are $60 and $140 respectively.



Before making your decisions please examine the above diagram. Please tick (√) your decisions -- LEFT or RIGHT – below.

<u>**Your decision**</u> **as Person A**:

 LEFT RIGHT

<u>**Your decision**</u> **as Person B if Person A had chosen LEFT**: LEFT RIGHT

<u>**Your decision**</u> **as Person B if Person A had chosen RIGHT**: LEFT RIGHT

Public Goods Game

Both **Person A** and **Person B** are **endowed with $80**. Each decides how much of $80 (*between $0 to $80 inclusive*) to deposit into a common pool and how much to keep. The deposits from both persons into the pool will be **multiplied by 1.6**. After both have made their deposit decisions without knowing each other's decisions, the amount in the pool (*after multiplication by 1.6*) will be divided equally between the both persons.

There are two parts to each participant's earning:

- Your endowment of **$80 minus your deposit** to the pool.
- The person's **share of the common pool**, i.e., half of 1.6 x total deposits by both persons.

Illustrative exercises (**Answer key at bottom of page)**. *Here are some exercises to help you understand the decision situation.*
1. Both deposit zero to the pool. Person A's earnings is _____. Person B's earnings is _____.
2. Both persons deposit $80 to the pool. Person A's earnings is ____, Person B's earnings is _____. Notice that Persons A and B have symmetric roles.

After the decision sheets have been collected, your earnings will be computed based on both your decision and the other participant's decision.

Your decision as Person A: I will deposit _______ (*between $0 and $20 inclusive*) to the common pool.

Risk Task

This situation involves your guessing the color – red or black – of a card drawn randomly from a deck of 20 cards, comprising **10 black** cards and **10 red** cards.

Option A: You guess the color – black or red – and then draw a card from the deck of 20 cards. If you make a correct guess, you receive $60; otherwise, you receive nothing. That is: **50% chance of receiving $60 and 50% chance of receiving $0.**

The **Option B** column lists **10 amounts** (*displayed in an ascending manner*) each corresponding to what you will receive for sure if you choose this option.

DECISION: For each of the 10 rows, please indicate your decision in the final column with a tick (√).

	Option A	Option B	Decision
1	50% of receiving $240, 50% of receiving $0	Receiving $60 for sure	A ☐ B ☐
2	50% of receiving $240, 50% of receiving $0	Receiving $76 for sure	A ☐ B ☐
3	50% of receiving $240, 50% of receiving $0	Receiving $92 for sure	A ☐ B ☐
4	50% of receiving $240, 50% of receiving $0	Receiving $100 for sure	A ☐ B ☐
5	50% of receiving $240, 50% of receiving $0	Receiving $108 for sure	A ☐ B ☐
6	50% of receiving $240, 50% of receiving $0	Receiving $116 for sure	A ☐ B ☐
7	50% of receiving $240, 50% of receiving $0	Receiving $120 for sure	A ☐ B ☐
8	50% of receiving $240, 50% of receiving $0	Receiving $124 for sure	A ☐ B ☐
9	50% of receiving $240, 50% of receiving $0	Receiving $132 for sure	A ☐ B ☐
10	50% of receiving $240, 50% of receiving $0	Receiving $140 for sure	A ☐ B ☐

2.5.2 Appendix B: First Stage Results of Instrumental Regression for the Public Goods Game

	(1)	(2)
VARIABLES	Percent of Paddy	Percent of Paddy
Rice suitability index	0.0102***	0.0106***
	(0.0003)	(0.0003)
Constant	0.0431	-0.0868
	(0.0036)	(0.0157)
Controls	No	Yes
Observations	1022	965
F-stat	1475.1	413.15

Notes: Standard errors in parentheses clustered at the province level. * significant at 10%; ** significant at 5%; *** significant at 1%. Controls include Sex, Income, GDP 2010, and Wave 2010. Sex is a dummy variable for which 1 means female and 0 means male. Income and GDP 2010 numbers are reported in units of 10,000 RMB. Wave 2010 is a dummy variable for which 1 means the 2010 study and 0 means the 2012 study. F-stat is the F statistic of the first stage result in the instrumental regression.

2.5.3 Appendix C: Results of Trustworthiness in the Trust Game

	(1)	(2)	(3)	(4)
	OLS	IV	OLS	IV
VARIABLES	Slope	Slope	Intercept	Intercept
Percent of paddy	-0.0150	-0.00710	-0.125	-0.178
	(0.0164)	(0.0232)	(0.219)	(0.286)
Sex	-0.0167	-0.0167	-0.0654	-0.0655
	(0.0128)	(0.0125)	(0.215)	(0.210)
Family income	-0.00345***	-0.00347***	0.00789	0.00800
	(0.00103)	(0.00101)	(0.0152)	(0.0149)
GDP 2010	-0.00224	-0.00222	-0.00147	-0.00158
	(0.00358)	(0.00355)	(0.0473)	(0.0463)
Wave 2010	0.0290**	0.0290***	-0.0119	-0.0122
	(0.0108)	(0.0106)	(0.165)	(0.162)
Constant	0.467***	0.465***	-2.638***	-2.622***
	(0.0222)	(0.0234)	(0.249)	(0.258)
Observations	946	946	946	946
R-squared	0.031	0.031	0.000	0.000

Notes: Standard errors in parentheses clustered at the province level. * significant at 10%; ** significant at 5%; *** significant at 1%. Slope is the slope of the regression line of trustee's return money on the received money. Intercept is the intercept of the regression line of trustee's return money on the received money. Sex is a dummy variable for which 1 means female and 0 means male. Income and GDP 2010 numbers are reported in units of 10,000 RMB. Wave 2010 is a dummy variable for which 1 means the 2010 study and 0 means the 2012 study.

Chapter 3

Does the Stake Size Matter in Penalty Kick? - An Experimental Investigation of the Two-Stage Matching Pennies Game[9]

3.1 Introduction

Mixed strategy equilibrium is the cornerstone of game theory. A special family of finite games, the matching pennies game, has been widely adopted in empirical tests of the predictions of mixed strategy equilibrium. The reasons are twofold (Colin Camerer, 2003): (1) there are no equilibrium selection issues since it has a unique mixed strategy equilibrium, and (2) the concern of social preference is minimized due to the zero-sum payoff structure.

Mark Walker and John Wooders (2001) have pioneered the realm of using data from sports games to test the prediction of mixed strategy equilibrium. Upon analyzing the data from tennis championship series, they found that the players' frequencies of choosing which side to serve the ball are consistent with the predictions of mixed strategy equilibrium. Ignacio Palacios-Huerta (2003) further explored data of penalty kicks in football games, concluding that the players' frequencies of choosing which side to kick the ball in a penalty are in agreement with the prediction of the mixed strategy equilibrium.

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[9] This is a joint work with Soo Hong Chew and Bin Miao. We thank the comments and suggestions from Roy Chen, Xing Zhang, Changcheng Song, and Songfa Zhong.

Both the tennis game and penalty kick game are endowed with a matching-penny structure; hence the results in both Mark Walker and John Wooders (2001) and Ignacio Palacios-Huerta (2003) provide strong evidence for mixed strategy equilibrium in the field. It is noteworthy that the above two studies have assumed expected utility when deriving the predictions of mixed strategy equilibrium. But sports games usually involve not only strategic uncertainty but also objective risks. For example, it is not guaranteed that the penalty taker in a football game can obtain a positive payoff even when the goal keeper chooses the wrong side, since there remains a possibility that the penalty taker may fail to goal. This suggests that sports games have a two-stage structure. Consider the following representative two-stage matching-penny style game between a pursuer and an evader:

Figure 3.1 Two-stage Matching Pennies Game

		Evader	
		Red	**Black**
Pursuer	**Red**	1/3 (\$x, \$0) 2/3 (\$0, \$x)	(\$0, \$x)
	Black	(\$0, \$x)	2/3 (\$x, \$0) 1/3 (\$0, \$x)

In Figure 3.1 the payoffs are not deterministic given the specific strategy profile of the two players. Notice that given a mixed strategy pR+(1-p)B of the pursuer, choosing the pure strategy Red results in a compound lottery for the evader, i.e. a p probability of obtaining a simple lottery (1/3,0; 2/3,x) and a (1-p) probability of obtaining a degenerate lottery (1,x). Similarly, choosing the pure strategy Black results in a compound lottery delivering (1, x) with a p probability and (2/3, 0; 1/3, x) with probability (1-p). Expected utility assumes reduction for compound lotteries, and the resultant mixed strategy equilibrium under expected utility does not depend on the value of x, which is (2/3R+1/3B, 2/3R+1/3B).

This prediction of stake-size independent equilibrium has been challenged by Avinash Dixit and Susan Skeath (1999). They argue that stake size may have an effect in sports games as football game players tend to choose a 'safer' strategy in important games compared with unimportant ones. By reducing compound lotteries, players do not differentiate strategic uncertainty from objective risk. There has been evidence (Robin Chark and Soo Hong Chew, 2013) attesting to the fact that players distinguish games involving strategic uncertainty from those involving objective risk. In this regard, the prediction of expected utility in two-stage games remains questionable. In particular, Simon Grant et al. (2001) have shown that the recursive expected utility theory, which allows distinct expected utilities in evaluating different orders of risks in compound lotteries, can generate a stake-size dependent mixed strategy equilibrium in two-stage games.

In this study, we have experimentally investigated the stake-size effect in two-stage games, and found that the frequencies of strategies vary as a function of the stake size. Therefore, our results suggest against reduction and the expected utility theory, and further elucidate the empirical literature on mixed strategy equilibrium. In particular, our results imply that the prediction of the mixed strategy equilibrium under expected utility in the field remains valid only if it is robust to the variation of stake sizes, i.e. the predictions of mixed strategy equilibrium hold even after differentiating the data between 'important' games and 'unimportant' games when analyzing the data of sports games from the field.

Some other experimental studies have also explored the mixed strategy equilibrium. Ignacio Palacios - Huerta and Oscar Volij (2008), in their comparison of the performance of professional football players with that of students, shown that the former behave according to the prediction of the mixed strategy equilibrium whereas the latter do not. With the same data set, John Wooders (2010) pointed out that the subjects' individual behaviors were inconsistent with the theory. Steven D. Levitt et al. (2010), in examining the Poker player's performance in the mixed strategy equilibrium, found that the students behave even more closely to the prediction of mixed strategy equilibrium.

Experimentally, Barry O'Neill (1987) has used a two-outcome design with the risk-attitude free equilibrium, and the results accord well with the theoretical predictions at the group level. Some follow-up studies (James N Brown and Robert W Rosenthal, 1990, Jacob K Goeree et al., 2003, Jack Ochs, 1995) have pointed out that there are many behavioral biases for human subjects and that people's behaviors, especially at the individual level, are inconsistent with the prediction of the theory: the frequency of the actions deviates from the theory, and autocorrelation arises among the actions across the time. Robert W Rosenthal et al. (2003) compared people's behaviors in the equivalent deterministic game and random game, and found their behaviors differ systematically.

There is a body of literature on the stake size effect in the experimental games. With a lottery-choice experiment, Charles A Holt and Susan K Laury (2002) have shown that a high stake size renders people more risk averse. For the ultimatum game, many studies have reported that respondents do not change their behavior significantly as the stakes increase (Lisa A Cameron, 1999, Bertrand Munier and Costin Zaharia, 2002, Robert Slonim and Alvin E Roth, 1998), while Andersen etc. (2011) have provided a positive stake size effect. For some tasks with performance-contingent payments, Dan Ariely et al. (2009) have found that under extreme high incentives, people's performance level even decreases. Compared with this literature, our study is more closely connected with theoretical predictions - specifically the stake size effect in the situation of strategic interactions.

3.2 Experimental Design

We adopt a two-stage matching penny game as shown in Figure 2.1, in which a particular strategy profiles yields lotteries on the payoffs for the players. This game appears in Robert W Rosenthal, Jason Shachat and Mark Walker (2003), Ignacio Palacios - Huerta and Oscar Volij (2008), and Steven D. Levitt, John A. List and David H. Reiley (2010).

Three players are involved in the game, one pursuer, one evader and one judge. The pursuer and the evader choose either red or black poker cards simultaneously, and the judge determines the final payoffs by throwing a die. For example, when both players choose red cards, the judge will throw a six-side die. If the outcome of the die is 1 or 2, the pursuer will get x and the evader 0; if otherwise, the evader will get x and the pursuer 0.[10]

We adopt a within-subject design with two levels of stake sizes, RMB 5 and RMB 100. For each stake size, the game is played 100 rounds. In order to control for the order effect, we have conducted the experiment in two different ordering with the lower stake size appearing first and the higher stake size appearing later. In the low-stake-first treatment, the subjects first play the game with the stake size of RMB 5 for 100 rounds and then with the stake size of RMB 100 for another 100 rounds; in the high-stake-first treatment, the order is reversed.

In the experiment, the role of each subject was randomly determined before the experiment began and was unchanged throughout the experiment. At the end, each pair of pursuer and evader was paid based on his or her randomly selected decisions in the game in addition to

[10] See Appendix A5 for detailed experimental instructions.

the RMB 30 show-up fee. One decision is selected for one stake size using die. The judge received a fixed payment of RMB 40.

A total of 123 undergraduates from the Shanghai University of Finance and Economics were recruited as the participants using online advertisement. The experiment, comprising 4 sessions with around 30 subjects in each session, was conducted by the authors with a research assistant. There were 63 subjects for the low-stake-first treatment and 60 for the high-stake-first treatment. Upon arrival, the subjects were given the consent form approved by the Institutional Review Board of the National University of Singapore. Subsequently, general instructions were read to the subjects followed by our demonstration of several examples. Most subjects completed the tasks within 40 minutes. The payment stage took about 10 minutes.

3.3 Theoretical predictions

This section analyzes the theoretical implications of reduction axiom on two-stage games. Consider the two-stage game in Figure 1. The pursuer choosing action Red with a p probability yields the following two compound lotteries for the evader when choosing Red (R) and Black (B) respectively:

Choosing R: p probability of receiving $\left(\frac{1}{3}, 0; \frac{2}{3}, x\right)$ and $1-p$ probability of receiving $(1, x)$;

Choosing B: p probability of receiving $(1, x)$ and $1 - p$ probability of receiving $\left(\frac{2}{3}, 0; \frac{1}{3}, x\right)$.

Similarly, the evader choosing action Red with a q probability yields the following two compound lotteries for the pursuer when choosing Red and Black respectively:

Choosing R: q probability of receiving $\left(\frac{2}{3}, 0; \frac{1}{3}, x\right)$ and $1 - q$ probability of receiving $(1,0)$;

Choosing B: q probability of receiving $(1,0)$ and $1 - q$ chance of receiving $\left(\frac{1}{3}, 0; \frac{2}{3}, x\right)$.

With reduction, the evader chooses R to obtain $\left(\frac{p}{3}, 0;\ 1 - \frac{p}{3}, x\right)$, and chooses B to obtain $\left(\frac{2-2p}{3}, 0;\ \frac{1+2p}{3}, x\right)$, whereas the pursuer chooses R to obtain $\left(1 - \frac{q}{3}, 0;\ \frac{q}{3}, x\right)$, and chooses B to obtain $\left(\frac{1+2q}{3}, 0;\ \frac{2-2q}{3}, x\right)$. The game permits the following unique mixed strategy equilibrium:

$p^* = \frac{2}{3}$ and $q^* = \frac{2}{3}$.

Note that this equilibrium is independent of risk attitudes. In fact, the equilibrium remains robust under a broader class of utility functions, namely stochastic dominance. The reason is that there are only two outcomes 0 and x; equivalence between the two lotteries $\left(\frac{p}{3}, 0;\ 1 - \frac{p}{3}, x\right)$

and $\left(\frac{2-2p}{3}, 0;\ \frac{1+2p}{3}, x\right)$ implies $\frac{p}{3} = \frac{2-2p}{3}$ as long as the utility function satisfies stochastic dominance.[11]

Under the general class of utilities, a further implication is that the equilibrium is invariant to the change of x. Thus, an observation of the stake-size dependent mixed strategy equilibrium would imply either the failure of stochastic dominance or reduction axiom.

As dominance is relatively a weak assumption, we proceed to consider the implications of models with non-reduction on the stake-size effect. In particular, we consider two-stage expected utility (David M Kreps and Evan L Porteus, 1978) in evaluating compound lotteries.

Given a compound lottery $\left(p, \left(\frac{1}{3}, 0;\ \frac{2}{3}, x\right);\ 1-p, (1, x)\right)$, the evaluation of two-stage expected utility is $pv\left(\frac{1}{3}u(0) + \frac{2}{3}u(x)\right) + (1 - p)v\big(u(x)\big)$, where v is the stage-1 expected utility index and u is the stage-2 expected utility index. Therefore, u and v encapsulate the attitudes towards objective risk and towards strategic uncertainty, respectively.

In the case that $u(\,)$ and $v(\,)$ are identical, the decision maker does not differentiate the two sources of uncertainty and the utility function reduces to expected utility.

Under two-stage expected utility, the equilibrium strategy p^* is determined by the following equation

[11] This class of utility functions includes expected utility, quadratic utility, betweenness and rank-dependent utility. We later analyze QRE, which does not satisfy stochastic dominance.

$$pv\left(\frac{1}{3}u(0)+\frac{2}{3}u(x)\right)+(1-p)v\big(u(x)\big)$$

$$=pv\big(u(x)\big)+(1-p)v\left(\frac{2}{3}u(0)+\frac{1}{3}u(x)\right)$$

For the simplicity of analysis, we normalize $u(0)=0$ and $u(x)=a$, and we have the following

$$pv\left(\frac{2}{3}a\right)+(1-p)v(a)=pv(a)+(1-p)v\left(\frac{1}{3}a\right),$$

which can be rewritten as

$$\frac{p}{1-p}=\frac{v(a)-v(\frac{1}{3}a)}{v\left(\frac{2}{3}a\right)-v(\frac{1}{3}a)}.$$

Similarly, we have

$$\frac{q}{1-q}=\frac{v\left(\frac{2}{3}a\right)}{v\left(\frac{1}{3}a\right)}.$$

The equilibrium (p^*,q^*) depends on the curvature of v, and we shall have the stake-size variant equilibrium if, for example, v is not homogeneous.

Some other two-stage utility specifications that do not admit reduction of compound lotteries can also generate the stake-size dependent equilibrium. We do not discuss them in details here since we aim to identify the qualitative stake-size effect rather than to provide exact predictions on the directions of the effect.

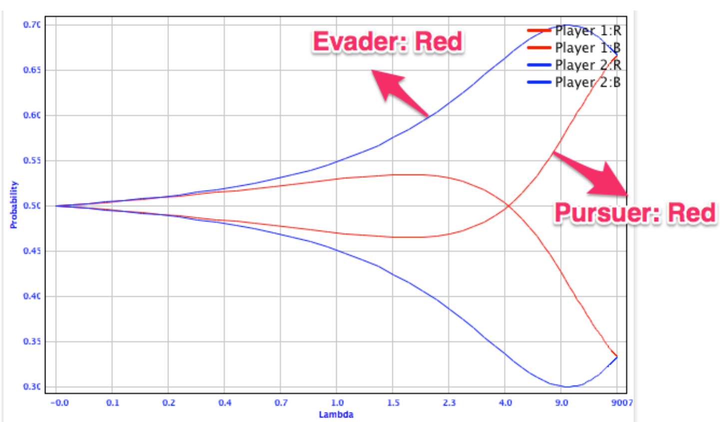
On the other side, it is also possible to have the stake-size effect in the absence of stochastic dominance for simple lotteries. Next, we consider, for example, the predictions of quantal response equilibrium

(Richard D McKelvey and Thomas R Palfrey, 1995). The theory assumes choice errors in equilibrium, and admits a logit form of choice probability. The quantal equilibrium is determined by the following system of equations[12]:

$$\begin{cases} p = e^{\lambda(\frac{1}{3}q)} / (e^{\lambda(\frac{1}{3}q)} + e^{\lambda(\frac{2}{3}(1-q))}), \\ q = e^{\lambda(\frac{2}{3}p+(1-p))} / (e^{\lambda(\frac{2}{3}p+(1-p))} + e^{\lambda(p+\frac{1}{3}(1-p))}) \end{cases}$$

Here λ is a parameter that measures the degree of errors that may be made by a decision maker when choosing the equilibrium strategy; a higher λ implies a lower rate of choice errors that may be made by the decision maker. The system approaches Nash equilibrium as λ becomes increasingly close to infinity. Figure 3.2 plots the quantal response equilibrium with respect to variation in λ generated by Gambit (Richard D. McKelvey et al., 2014).

Figure 3.2 Quantal Response Equilibrium with Variation in λ



Notes: The horizontal axis is the value of λ, and the vertical axis is the frequency of choosing red cards of players. The two arrows in the figure show the frequency of choosing red cards for the pursuer and the evader correspondingly.

[12] Here we normalize the prize in each period as x=1 Yuan.

One immediate implication of the quantal response equilibrium is that it is stake-size dependent, since changes in the stake sizes have the same effect as changes in λ in the system of equations. In particular, an increase in the stake sizes is the same as an increase in λ, which leads to an observation that is closer to the Nash equilibrium.

3.4 Results

Table A1 in appendix outlines the frequencies of choosing Red for each pursuer and evader by different stake sizes[13]. Session 1 and 2 correspond to the high-stake-first treatment, while Session 3 and 4 correspond to the low-stake-first treatment. The third and fourth columns are the frequencies for the pursuer choosing red cards in the first 100 rounds and the remaining 100 rounds, and so are the sixth and seventh columns for the evader.

Overall, we observe the following stylized patterns.

3.4.1 Equilibrium Frequencies and the Stake Size Effect

From Table A1, we notice that the subjects' frequencies of choosing red cards vary considerably, many of which deviate from the expected utility equilibrium prediction of 2/3. In addition, a simple t test of the two stake size treatments in Column 5 and 8 of Table 3 demonstrates

[13] 4 pairs of players didn't understand the game properly or didn't want to seriously play – they almost always chose red cards in the whole treatment. When we compare the group level choice frequencies, we delete them and focus on our discussion on the normal behavior. In appendix, we also show the results with all the subjects.

a statistically significant stake-size effect for 11 out of 41 pursuers and 9 out of 41 evaders.

We test the stake size effect at the group level. Analysis of data from all the 4 sessions according to their stake size yields the insight that both the pursuer and the evader exhibit the treatment effect of stake size, which is statistically significant under the paired t test and the Wilcoxon test from Table 3.1. Notice that the overall comparison has cancelled out the possible order effect. From Table 3.1[14], in Sessions 1 and 2, the frequency (at the group level) of choosing red cards increases from the low stake size treatment to high stake size treatment for both the pursuer and the evader, which are statistically significant. In the reverse order Sessions 3 and 4, the pattern is similar though not statistically significant.

Table 3.1 Group Level Frequency Data

Session	Role	Low Stake-Size Treatment	High Stake-Size Treatment	Paired t test P-value	Wilcoxon test P-value
All	Pursuer	0.5141	0.5646	0.0034	0.0063
All	Evader	0.5973	0.6284	0.0569	0.0309
1, 2	Pursuer	0.512	0.575	0.0016	0.0019
1, 2	Evader	0.604	0.653	0.0407	0.0418
3, 4	Pursuer	0.5165	0.5524	0.2339	0.4925
3, 4	Evader	0.5894	0.5994	0.6419	0.3307

In the first 100 rounds, the frequency (at the group level) of choosing red cards is below 2/3 whereas, in the later 100 rounds, they will approach but not arrive at 2/3. This suggests a learning effect. To mitigate

[14] In Appendix 3.7.3, we show the group level frequency data with all the subjects including the 4 pairs of outliers. We still find a clear stake-size effect for the pursuer.

the influence of the learning effect, we also performed a between-subject comparison between the frequency of choosing red cards in the first 100 rounds of Session 1 and 2 with that in the Session 3 and 4. The first column in Table 3.2[15] shows the p value of the t test between the first 100 rounds in Session 1 and 2 with that in Session 3 and 4. The pursuer chooses red cards with a frequency of 0.512 in the low stake size treatment but with a frequency of 0.5524 in the high stake size treatment, both of which are statistically significant with $p = 0.0142$ in the t test. Conversely, the evader chooses red cards with a frequency of approximately 0.6 in both treatments (0.604 in Session 1 and 2 and 0.5994 in Session 3 and 4), both of which are statistically insignificant. For the remaining 100 rounds, we observed a pronounced treatment effect. The pursuer chooses red cards with a frequency 0.575 in Sessions 1 and 2 and with a frequency of 0.5165 in Sessions 3 and Session 4; similarly, the evader chooses red cards with a frequency of 0.653 in Sessions 1 and Session 2 and a frequency of 0.5894 in Sessions 3 and 4; they are both significant with a $p < 0.001$ in the t test.

Table 3.2 Between Subject Comparison

	First 100 rounds of Session 1, Session 2 vs. Session 3, Session 4	**Remaining 100 rounds of Session 1, Session 2 vs. Session 3, Session 4**
Pursuer	0.0142	0.0004
Evader	0.7764	0.0001

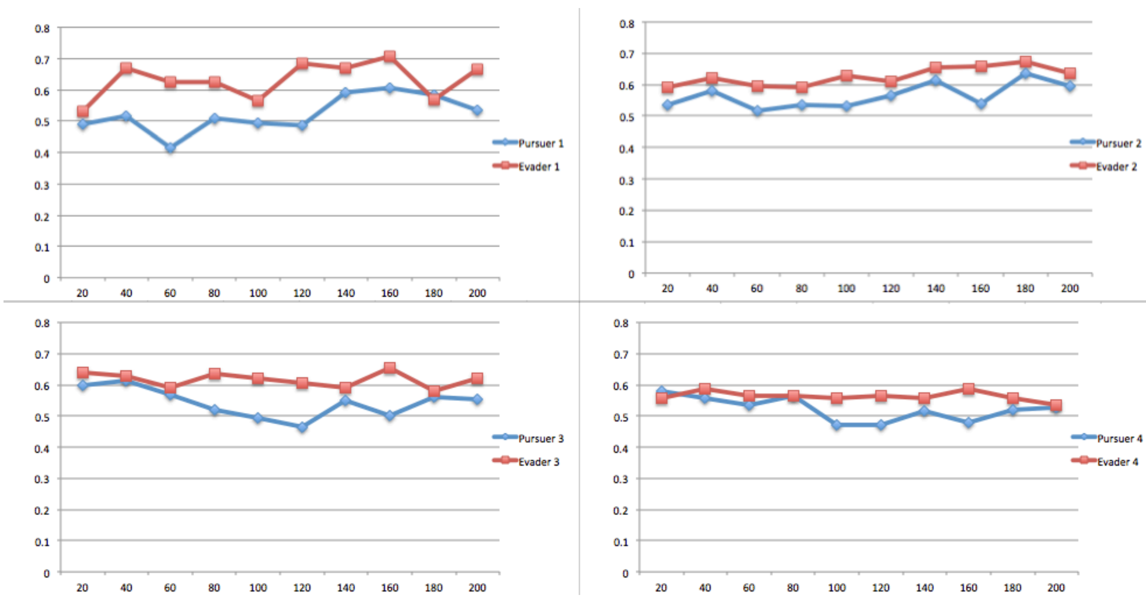
Notes: the number in each cell is the p-value of the t test.

[15] In Appendix 3.7.4, we show the between subject comparison with all the subjects including the 4 pairs of outliers. We still find a clear stake-size effect for the pursuer.

3.4.2 Asymmetry of Player Roles

Figure 3.3 plots the frequency of choosing red cards in each 20 periods, and this gives us the information of their learning dynamics. It is noteworthy that the Evader chooses red cards with a higher frequency across time in almost all the four experimental sessions. This asymmetric behavior between the two roles has also been observed by Robert W Rosenthal, Jason Shachat and Mark Walker (2003).

Figure 3.3 Learning Dynamics



3.4.3 Serial Correlation

Negative serial correlation is widely observed in laboratory data (Jack Ochs, 1995) and field data (Mark Walker and John Wooders, 2001), and it is widely believed to be due to people's behavioral bias on random events (Colin Camerer, 2003). Robert W Rosenthal, Jason Shachat and Mark Walker (2003) have found strong positive serial correlations in this experimental game. In Table A2 in Appendix, much heterogeneity is observed for our subjects on serial correlations: both positive and negative correlations are observed, and many of which are statistically significant. This pattern corroborates the findings from previous studies and attributes the observed serial correlation to randomness of bias in human cognition. Since our main theoretical predictions focus on the frequency of choice rather than on serial correlation, we will not discuss it further here.

3.5 Discussion

The standard expected utility theory gives rise to several sharp predictions in the two-stage matching pennies game: (1) the equilibrium frequency should equal 2/3; (2) there is no stake size effect; and (3) there is no serial correlation across time. The inferences drawn from our data, however, reject all these predictions. This implies a failure of expected utility in this situation, and suggests that the observed patterns in choice frequencies can be accounted for by relaxing some assumptions in expected utility, i.e., reduction of compound lotteries and stochastic dominance. It leads to the two theory candidates – the recursive expected utility theory and the quantal response equilibrium, respectively.

As regards the stake size effect, the recursive expected utility theory yields a clear prediction if the subject has some utility functional forms whereas the quantal response equilibrium predicts that the equilibrium frequency will be closer to the Nash equilibrium in the high stake size treatment than that in the low stake size treatment. The intuition is that, when the subjects face a high stake size prize, they may make less random error since the cost is higher compared with those in the low stake size treatment.

For the fact that the observed equilibrium frequency doesn't equal to 2/3, as it is shown in Section 3.3 the recursive expected utility theory could explain it. The quantal response equilibrium predicts that the equilibrium frequency of the pursuer is below 2/3 and the evader doesn't equal to 2/3 in most of the cases.

A pattern of asymmetric equilibrium frequency is also observed: the pursuer chose the red cards with a higher frequency than the evader did in all the sessions. The recursive expected utility theory has no specific prediction but can explain it with specific functional form; while the quantal response equilibrium provides an exact sharp prediction on this.

As regards the serial correlation, neither the quantal response equilibrium nor the recursive expected utility theory provides predictions. The quantal response equilibrium are used to explain the learning effect if we permit the randomness parameter λ to increase across time. There is a learning effect in our data, and the quantal response equilibrium fares better in that capacity.

Table 3.3 summarizes the aforesaid discussion. The overall notion is that the quantal response equilibrium seems to be better at explaining the multiplicity of patterns in our experimental data, in addition to meritoriously using fewer parameters and to concisely organizing several patterns in the data.

Table 3.3 Comparisons of Theories and Evidence

Experimental Facts	Standard Expected Utility	Recursive Expected Utility	Quantal Response Equilibrium
Stake size effect	No	Yes	Yes
Equilibrium frequency is not 2/3	No	Yes	Yes
Asymmetric role effect	No	No prediction	Yes
Serial correlation	No	No	No

To measure the quantitative effect of the stake size effect, we estimated the quantal response equilibrium model with maximum likelihood method. We normalized the matching penny game payoff in each round as 1 Yuan for both low and high stake size treatment. The QRE model's log likelihood function is

$$\log L = \sum_{i=1}^{n} [y_{Pi} * \log\big(p(\lambda)\big) + (1 - y_{Pi}) * \log\big(1 - p(\lambda)\big) + y_{Ei} * \log\big(q(\lambda)\big) + (1 - y_{Ei}) * \log\big(1 - q(\lambda)\big)],$$

where y_{Pi} and y_{Ei} is the choice dummy of red cards for the pursuer and the evader respectively; p and q comes from the following nonlinear simultaneous equation system

$$\begin{cases} p = e^{\lambda(\frac{1}{3}q)} / (e^{\lambda(\frac{1}{3}q)} + e^{\lambda(\frac{2}{3}(1-q))}), \\ q = e^{\lambda(\frac{2}{3}p+(1-p))} \Big/ \left(e^{\lambda\left(\frac{2}{3}p+(1-p)\right)} + e^{\lambda\left(p+\frac{1}{3}(1-p)\right)} \right). \end{cases}$$

In order to estimate the treatment effect, we let $\lambda = b_0 + b_1 * High\_stake$. Here $High\_stake$ is the treatment dummy in which 1 means high stake treatment and 0 means low stake treatment. The following Table 3.4 shows the estimation results. The constant b_0 is 2.1516 and the treatment coefficient b_1 is 3.7879, and both are significantly at 1% level. This implies that for the low stake size treatment, the purser's predicted frequency of choosing red is 0.4672, and the evader's is 0.6057; for the high stake size treatment, the Purser's is 0.5329, and the evader's is 0.6888.

Table 3.4 The Stake Size Effect in QRE

	Coefficient	**Standard Error**
b_0	2.1516 ***	0.2320
b_1	3.7879 ***	0.7446

Notes: *** significant at 1% level.

3.6 Conclusions

In our examination of the stake-size effect in a two-stage matching pennies game, we have found evidence against the predictions of the expected utility theory for the mixed strategy equilibrium. In addition, we have demonstrated that the two-stage expected utility theory and the quantal response equilibrium theory can account for the effect by relaxing some properties of expected utility theory, including reduction of compound lotteries and stochastic dominance. Our results have further implications for the field studies on mixed strategy equilibrium; in particular, our results suggest the need to differentiate between different stake sizes in the field. Lastly, we would like to point out we utilize the stake-size independence property of two-stage games under expected utility theory in this study; some other properties of two-stage games are also of interest in the empirical study – for example, the manipulation of the stage-2 lotteries for different players to have different correlation structures for analysis of the impact of social preference on equilibrium. This new topic warrants further investigations in our future studies.

3.7 Appendix

3.7.1 Appendix Table A1 Pair Level Data

Session	Pair	Pursue 1	Pursuer 2	t test p-value	Evader 1	Evader2	t test p-value
1	101	0.3	0.44	0.0405**	0.51	0.53	0.7785
1	102	0.41	0.36	0.47	0.56	0.58	0.7765
1	103	0.49	0.56	0.324	0.64	0.65	0.8833
1	104	0.54	0.74	0.0031***	0.78	0.71	0.2583
1	105	0.52	0.65	0.0626*	0.6	0.65	0.4677
1	106	0.47	0.67	0.0041***	0.49	0.59	0.1575
1	107	0.51	0.57	0.3972	0.61	0.65	0.5603
1	108	0.51	0.47	0.5738	0.44	0.79	0***
1	109	0.46	0.53	0.3246	0.76	0.73	0.6285
1	110	0.64	0.61	0.6632	0.64	0.71	0.293
2	201	0.74	0.83	0.1226	0.78	0.82	0.482
2	202	0.57	0.62	0.4739	0.66	0.77	0.0857*
2	203	0.47	0.47	1	0.51	0.48	0.6732
2	204	0.46	0.55	0.205	0.54	0.67	0.0605*
2	205	0.66	1	0***	0.74	0.96	0***
2	206	0.65	0.66	0.8825	0.75	0.84	0.1161
2	207	0.44	0.45	0.8876	0.51	0.5	0.8882
2	208	0.52	0.58	0.3963	0.49	0.45	0.5732
2	209	0.5	0.49	0.8882	0.42	0.61	0.007***
2	210	0.53	0.71	0.0086***	0.85	0.75	0.0778*
2	211	0.51	0.54	0.6729	0.54	0.58	0.5711
3	301	0.54	0.54	1	0.72	0.68	0.5395
3	302	0.51	0.53	0.7785	0.5	0.48	0.7786
3	303	0.78	0.43	0***	0.8	0.58	0.0007***
3	304	0.57	0.63	0.389	0.6	0.63	0.6648
3	305	0.44	0.56	0.0905*	0.52	0.46	0.3986
3	306	0.76	0.56	0.0027	0.62	0.52	0.1547
3	307	0.48	0.51	0.6732	0.52	0.77	0.0002***
3	308	0.41	0.48	0.3217	0.53	0.52	0.8881
3	309	0.57	0.54	0.6714	0.69	0.72	0.6438
3	310	0.54	0.48	0.3986	0.73	0.73	0.7775
4	401	0.65	0.58	0.3115	0.54	0.56	0.7775
4	402	0.49	0.49	1	0.45	0.5	0.4814
4	403	0.5	0.45	0.4814	0.54	0.56	0.7775
4	404	0.97	1	0.0817	1	1	1
4	405	0.46	0.46	1	0.62	0.57	0.4739
4	406	0.41	0.47	0.3953	0.6	0.55	0.477
4	407	0.72	0.5	0.0013***	0.63	0.63	1

4	408	0.41	0.99	0***	0.58	0.96	0***
4	409	0.56	0.99	0***	0.58	0.96	0***
4	410	0.56	0.57	0.8873	0.58	0.55	0.6706

3.7.2 Appendix Table A2 Serial Correlation Results

Session	Pair ID	Role	Run Test Z-value 1	Run Test P-value 1	Run Test Z-value 2	Run Test P-value 2
1	101	Pursuer	-3.6	0	0.55	0.58
1	101	Evader	3.22	0	2.46	0.01
1	102	Pursuer	-1.74	0.08	-0.45	0.65
1	102	Evader	1.78	0.08	2.95	0
1	103	Pursuer	2.42	0.02	-1.69	0.09
1	103	Evader	1.73	0.08	2.54	0.01
1	104	Pursuer	2.29	0.02	2.76	0.01
1	104	Evader	0.49	0.62	-0.29	0.77
1	105	Pursuer	0.82	0.41	0.55	0.58
1	105	Evader	1.47	0.14	2.76	0.01
1	106	Pursuer	1.05	0.3	0.41	0.69
1	106	Evader	0	1	0.96	0.34
1	107	Pursuer	0.41	0.68	2.46	0.01
1	107	Evader	0.93	0.35	-0.33	0.74
1	108	Pursuer	4.43	0	1.65	0.1
1	108	Evader	-0.67	0.5	0.55	0.58
1	109	Pursuer	-1.96	0.05	-2.99	0
1	109	Evader	-0.96	0.34	-1.9	0.06
1	110	Pursuer	1.73	0.08	1.99	0.05
1	110	Evader	-1.98	0.05	-5.18	0
2	201	Pursuer	-1.44	0.15	-0.8	0.43
2	201	Evader	-3.62	0	-2.92	0
2	202	Pursuer	-0.41	0.68	-1.95	0.05
2	202	Evader	-1.99	0.05	-1.54	0.12
2	203	Pursuer	5.28	0	4.27	0
2	203	Evader	-2.01	0.04	-0.39	0.7
2	204	Pursuer	1.48	0.14	5.58	0
2	204	Evader	1.48	0.14	0.41	0.69
2	206	Pursuer	-1.22	0.22	1.82	0.07
2	206	Evader	-2.29	0.02	-0.33	0.74
2	207	Pursuer	1.37	0.17	1.52	0.13
2	207	Evader	-0.2	0.84	-1.61	0.11
2	208	Pursuer	0.62	0.54	1.3	0.2
2	208	Evader	2.02	0.04	0.71	0.48
2	209	Pursuer	-2.21	0.03	-1.4	0.16
2	209	Evader	-0.77	0.44	-2.66	0.01
2	210	Pursuer	-2.99	0	-3.96	0
2	210	Evader	-0.6	0.55	0.67	0.5
2	211	Pursuer	0.41	0.68	2.09	0.04
2	211	Evader	0.27	0.79	-1.8	0.07

3	301	Pursuer	2.29	0.02	1.48	0.14
3	301	Evader	2.17	0.03	-0.12	0.9
3	302	Pursuer	3.02	0	0.44	0.66
3	302	Evader	2.21	0.03	5.65	0
3	303	Pursuer	-3.33	0	2.66	0.01
3	303	Evader	-1.26	0.21	0.47	0.64
3	304	Pursuer	-1.64	0.1	0.94	0.34
3	304	Evader	-0.42	0.68	2.24	0.03
3	305	Pursuer	0.55	0.58	0.55	0.58
3	305	Evader	1.22	0.22	0.47	0.64
3	306	Pursuer	0.97	0.33	2.19	0.03
3	306	Evader	-0.24	0.81	-0.99	0.32
3	307	Pursuer	0.02	0.99	0.81	0.42
3	307	Evader	0.22	0.83	0.74	0.46
3	308	Pursuer	-2.16	0.03	-0.59	0.56
3	308	Evader	-0.17	0.87	-1.39	0.16
3	309	Pursuer	2.46	0.01	2.9	0
3	309	Evader	-1.12	0.26	-3.83	0
3	310	Pursuer	2.29	0.02	3.64	0
3	310	Evader	1.43	0.15	2.49	0.01
4	401	Pursuer	4.53	0	2.53	0.01
4	401	Evader	-0.74	0.46	-0.26	0.46
4	402	Pursuer	3.42	0	3.22	0
4	402	Evader	3.55	0	4.02	0
4	403	Pursuer	0	1	3.76	0
4	403	Evader	0.06	0.95	0.35	0.73
4	405	Pursuer	0.38	0.38	-0.14	0.89
4	405	Evader	2.11	0.03	-0.7	0.01
4	406	Pursuer	-0.7	0.48	0.44	0.66
4	406	Evader	-0.21	0.83	1.12	0.26
4	407	Pursuer	-1.08	0.28	1.01	0.31
4	407	Evader	0.73	0.47	2.46	0.01
4	410	Pursuer	-0.06	0.95	-0.41	0.68
4	410	Evader	0.26	0.79	4.16	0

3.7.3 Appendix Table A3 Group Level Frequency Data with All Subjects

Session	Role	Low Stake-size Treatment	High Stake-size Treatment	Paired t test p-value
All	Pursuer	0.5526829	0.5812195	0.0091
All	Evader	0.6282927	0.6182927	0.3502
1, 2	Pursuer	0.5190476	0.5952381	0
1, 2	Evader	0.6104762	0.667619	0.0001
3, 4	Pursuer	0.588	0.5665	0.1688
3, 4	Evader	0.647	0.6175	0.0531

3.7.4 Appendix Table A4 Between Subject Comparison with All Subjects

	First 100 rounds Session 1 2 vs. Session 3 4	Second 100 rounds Session 1 2 vs. Session 3 4
Pursuer	0.0023	0.6375
Evader	0.6444	0.1644

Notes: the number in each cell is the p-value of the t test.

3.7.5 Appendix A5: Instructions for the Experiment[16]

You and the person seated next to you will repeatedly play a simple game of pursuit and evasion, or "hide and seek". Your roles have been randomly decided by drawing lots – one is the Pursuer, and the other is the Evader.

When the game begins, each privately chooses his or her color of the card – red or black – and puts it on the desk with the colored side facing down for concealment.

Now, both the Pursuer and the Evader open their cards. If the colors of the cards don't match (one card is red, the other black), the Evader will win, since the Pursuer has not found him. On the contrary, if the colors of cards match (both cards are red or both are black), the Pursuer finds the Evader, but whether he or she finally wins the round depends on the number generated by the throwing a dice.

In this case, the Judge will throw a dice to get a random number from 1 to 6. Notice that each number from 1 to 6 occurs with an equal probability.

The final outcomes are generated according to the following table:

	If dice is 1 or 2:	If dice is 3, 4, 5, or 6:
If both choose red:	The Pursuer wins	The Evader wins
If both choose black:	The Evader wins	The Pursuer wins
If one choose red, and the other choose black:	The dice is not thrown. The Evader wins	

When the winner is decided, the Judge will record the moves and the die number, the players' cards will be returned to them, and a new round begins. At this stage, the winner will get 5 Yuan.

The game will last for many rounds. In the first stage of the game, you will attend 100 rounds of the game like this; in the second stage, you will attend another 100 rounds of the similar game with a different payoff.

16 The original form is in Chinese.

First, each of you will get 30 Yuan for certain as the show-up fee of the experiment. Your additional payoff is determined as follows. Each of two stages of this game has 100 rounds. At the end of the experiment, we will randomly draw one of the 100 rounds and pay you according to the payoff in that period. We will total up your two chosen payoffs in the two stages of the game and pay you cash.

Bibliography

Alesina, Alberto; Nathan Nunn and Paola Giuliano. 2013. "On the Origins of Gender Roles: Women and the Plough." *Quarterly journal of Economics*, 128(2).
Allais, Maurice. 1953. "Le Comportement De L'homme Rationnel Devant Le Risque: Critique Des Postulats Et Axiomes De L'école Américaine." *Econometrica: Journal of the Econometric Society*, 503-46.
Amargos-Bosch, M.; A. Bortolozzi; M. V. Puig; J. Serrats; A. Adell; P. Celada; M. Toth; G. Mengod and F. Artigas. 2004. "Co-Expression and in Vivo Interaction of Serotonin1a and Serotonin2a Receptors in Pyramidal Neurons of Prefrontal Cortex." *Cereb Cortex*, 14(3), 281-99.
Amodio, Francesco and Giorgio Chiovelli. 2013. "Ethnicity, Migration and Conflict: Evidence from Contemporary South Africa."
Anderson, Jon; Stephen Burks; Colin DeYoung and Aldo Rustichini. 2011. "Toward the Integration of Personality Theory and Decision Theory in the Explanation of Economic Behavior," *Unpublished manuscript. Presented at the IZA workshop: Cognitive and non-cognitive skills.*
Andreoni, James. 1989. "Giving with Impure Altruism: Applications to Charity and Ricardian Equivalence." *The Journal of Political Economy*, 1447-58.
____. 1990. "Impure Altruism and Donations to Public Goods: A Theory of Warm-Glow Giving." *The Economic Journal*, 464-77.
Andreoni, James and John Miller. 2002. "Giving According to Garp: An Experimental Test of the Consistency of Preferences for Altruism." *Econometrica*, 70(2), 737-53.
Antypa, N.; A. Serretti and D. Rujescu. 2013. "Serotonergic Genes and Suicide: A Systematic Review." *Eur Neuropsychopharmacol*.
Ariely, Dan; Uri Gneezy; George Loewenstein and Nina Mazar. 2009. "Large Stakes and Big Mistakes." *The Review of Economic Studies*, 76(2), 451-69.
Ayalew, M.; H. Le-Niculescu; D. F. Levey; N. Jain; B. Changala; S. D. Patel; E. Winiger; A. Breier; A. Shekhar; R. Amdur, et al. 2012. "Convergent Functional Genomics of Schizophrenia: From Comprehensive Understanding to Genetic Risk Prediction." *Molecular psychiatry*.
Bagby, R. M.; G. J. Taylor and J. D. Parker. 1994. "The Twenty-Item Toronto Alexithymia Scale--Ii. Convergent, Discriminant, and Concurrent Validity." *J Psychosom Res*, 38(1), 33-40.
Becker, Anke; Thomas Deckers; Thomas Dohmen; Armin Falk and Fabian Kosse. 2012. "The Relationship between Economic Preferences and Psychological Personality Measures."
Ben-Efraim, YJ; D Wasserman; J Wasserman and M Sokolowski. 2013. "Family-Based Study of Htr2a in Suicide Attempts: Observed Gene,

Gene× Environment and Parent-of-Origin Associations." *Molecular psychiatry*, 18(7), 758-66.
Benjamin, D. J.; D. Cesarini; M. J. van der Loos; C. T. Dawes; P. D. Koellinger; P. K. Magnusson; C. F. Chabris; D. Conley; D. Laibson; M. Johannesson, et al. 2012. "The Genetic Architecture of Economic and Political Preferences." *Proceedings of the National Academy of Sciences of the United States of America*.
Benjamin, DJ; CF Chabris; EL Glaeser; V Gudnason; TB Harris; D Laibson; L Launer and S Purcell. 2007. "Genoeconomics." *Biosocial Surveys*, 304–35.
Bibby, Peter A and Eamonn Ferguson. 2011. "The Ability to Process Emotional Information Predicts Loss Aversion." *Personality and Individual Differences*, 51(3), 263-66.
Bigoni, Maria; Stefania Bortolotti; Marco Casari; Diego Gambetta and Francesca Pancotto. 2013. "Cooperation Hidden Frontiers: The Behavioral Foundations of the Italian North-South Divide."
Bishop, S.; J. Duncan and A. D. Lawrence. 2004. "Prefrontal Cortical Function and Anxiety: Controlling Attention to Threat-Related Stimuli." *Nat Neurosci*, 7(2), 184-88.
Blasi, G.; C. De Virgilio; A. Papazacharias; P. Taurisano; B. Gelao; L. Fazio; G. Ursini; L. Sinibaldi; I. Andriola; R. Masellis, et al. 2013. "Converging Evidence for the Association of Functional Genetic Variation in the Serotonin Receptor 2a Gene with Prefrontal Function and Olanzapine Treatment." *JAMA Psychiatry*, 70(9), 921-30.
Bogdan, R.; L. W. Hyde and A. R. Hariri. 2013. "A Neurogenetics Approach to Understanding Individual Differences in Brain, Behavior, and Risk for Psychopathology." *Molecular psychiatry*, 18(3), 288-99.
Borghans, Lex; Angela Lee Duckworth; James J Heckman and Bas Ter Weel. 2008. "The Economics and Psychology of Personality Traits." *Journal of Human Resources*, 43(4), 972-1059.
Bowles, Samuel. 1998. "Endogenous Preferences: The Cultural Consequences of Markets and Other Economic Institutions." *The Journal of Economic Literature*, 75-111.
Brown, James N and Robert W Rosenthal. 1990. "Testing the Minimax Hypothesis: A Re-Examination of O'neill's Game Experiment." *Econometrica*, 1065-81.
Bubar, M. J. and K. A. Cunningham. 2006. "Serotonin 5-Ht2a and 5-Ht2c Receptors as Potential Targets for Modulation of Psychostimulant Use and Dependence." *Curr Top Med Chem*, 6(18), 1971-85.
Camerer, C. F. 2007. "Neuroeconomics: Using Neuroscience to Make Economic Predictions." *The Economic Journal*, 117(519), C26-C42.
Camerer, Colin. 2003. *Behavioral Game Theory: Experiments in Strategic Interaction*. Princeton University Press.
Cameron, Lisa A. 1999. "Raising the Stakes in the Ultimatum Game: Experimental Evidence from Indonesia." *Economic Inquiry*, 37(1), 47-59.

Chark, Robin and Soo Hong Chew. 2013. "A Neuroimaging Study of Preference for Strategic Uncertainty." *Working Paper Available at SSRN:* http://ssrn.com/abstract=2016876.
Charness, Gary and Matthew Rabin. 2002. "Understanding Social Preferences with Simple Tests." *Quarterly journal of Economics*, 817-69.
Charney, E. and W. English. 2012. "Candidate Genes and Political Behavior." *American Political Science Review*, 106(01), 1-34.
Chaudhuri, Ananish. 2011. "Sustaining Cooperation in Laboratory Public Goods Experiments: A Selective Survey of the Literature." *Experimental Economics*, 14(1), 47-83.
Chen, Junshi; T Colin Campbell; Junyao Li; Richard Peto; J Boreham; Z Feng and L Youngman. 1990. *Diet Life-Style and Mortality in China: A Study of the Characteristics of 65 Chinese Counties*. Oxford, England: Oxford University Press.
Cloninger, C.R.; D.M. Svrakic and T.R. Prybeck. 1994. *The Temperament and Character Inventory (Tci): A Guide to Its Development and Use*. St. Louis: Center for Psychobiology of Personality.
Coleman, James, S. 1990. "Foundations of Social Theory." *Harvard University Press*.
Cooper, Chris and Salah Wahab. 2005. *Tourism in the Age of Globalisation*. Routledge.
Crisan, L. G.; S. Pana; R. Vulturar; R. M. Heilman; R. Szekely; B. Druga; N. Dragos and A. C. Miu. 2009. "Genetic Contributions of the Serotonin Transporter to Social Learning of Fear and Economic Decision Making." *Soc Cogn Affect Neurosci*, 4(4), 399-408.
da Cunha-Bang, Sophie; Dea Siggaard Stenbæk; Klaus Holst; Cecilie Löe Licht; Peter Steen Jensen; Vibe Gedsø Frokjaer; Erik Lykke Mortensen and Gitte Moos Knudsen. 2013. "Trait Aggression and Trait Impulsivity Are Not Related to Frontal Cortex 5-Ht2a Receptor Binding in Healthy Individuals." *Psychiatry Research: Neuroimaging*, 212(2), 125-31.
Daw, N. D.; S. Kakade and P. Dayan. 2002. "Opponent Interactions between Serotonin and Dopamine." *Neural Netw*, 15(4-6), 603-16.
De Martino, B.; C. F. Camerer and R. Adolphs. 2010. "Amygdala Damage Eliminates Monetary Loss Aversion." *Proceedings of the National Academy of Sciences of the United States of America*, 107(8), 3788-92.
Dixit, Avinash and Susan Skeath. 1999. "Games of Strategy," WW Norton & Company, New York,
Doya, K. 2008. "Modulators of Decision Making." *Nat Neurosci*, 11(4), 410-6.
Dreber, A. and C. L. Apicella. 2009. "The 7r Polymorphism in the Dopamine D4 Receptor Gene (Drd4) Is Associated with Financial Risk-Taking in Men." *Evolution and Human Behavior*, 30, 85-92.
Dreher, J. C. 2007. "Sensitivity of the Brain to Loss Aversion During Risky Gambles." *Trends Cogn Sci*, 11(7), 270-2.

Dube, Oeindrila; Omar García-Ponce and Kevin Thom. 2013. "From Maize to Haze: Trade Liberalization and the Growth of the Mexican Drug Sector."

Dufwenberg, Martin and Georg Kirchsteiger. 2004. "A Theory of Sequential Reciprocity." *Games and economic behavior*, 47(2), 268-98.

Ebdrup, B. H.; H. Rasmussen; J. Arnt and B. Glenthoj. 2011. "Serotonin 2a Receptor Antagonists for Treatment of Schizophrenia." *Expert Opin Investig Drugs*, 20(9), 1211-23.

Ebstein, R. P.; S. Israel; S. H. Chew; S. Zhong and A. Knafo. 2010. "Genetics of Human Social Behavior." *Neuron*, 65(6), 831-44.

Falkenberg, V. R.; B. M. Gurbaxani; E. R. Unger and M. S. Rajeevan. 2011. "Functional Genomics of Serotonin Receptor 2a (Htr2a): Interaction of Polymorphism, Methylation, Expression and Disease Association." *Neuromolecular Med*, 13(1), 66-76.

Fehr, Ernst and Klaus M Schmidt. 1999. "A Theory of Fairness, Competition, and Cooperation." *Quarterly journal of Economics*, 817-68.

Fei, Hsiao-Tung. 1939. *Peasant Life in China: A Field Study of Country Life in the Yangtze Valley*. London: George Routledge and Sons, Ltd.

Fincher, Corey L; Randy Thornhill; Damian R Murray and Mark Schaller. 2008. "Pathogen Prevalence Predicts Human Cross-Cultural Variability in Individualism/Collectivism." *Proceedings of the Royal Society B: Biological Sciences*, 275(1640), 1279-85.

Fisher, P. M.; C. C. Meltzer; J. C. Price; R. L. Coleman; S. K. Ziolko; C. Becker; E. L. Moses-Kolko; S. L. Berga and A. R. Hariri. 2009. "Medial Prefrontal Cortex 5-Ht(2a) Density Is Correlated with Amygdala Reactivity, Response Habituation, and Functional Coupling." *Cereb Cortex*, 19(11), 2499-507.

Fisman, Raymond; Pamela Jakiela and Shachar Kariv. 2014. "The Distributional Preferences of Americans," National Bureau of Economic Research,

Fisman, Raymond; Shachar Kariv and Daniel Markovits. 2007. "Individual Preferences for Giving." *The American Economic Review*, 1858-76.

Frokjaer, V. G.; M. Vinberg; D. Erritzoe; W. Baare; K. K. Holst; E. L. Mortensen; H. Arfan; J. Madsen; T. L. Jernigan; L. V. Kessing, et al. 2010. "Familial Risk for Mood Disorder and the Personality Risk Factor, Neuroticism, Interact in Their Association with Frontolimbic Serotonin 2a Receptor Binding." *Neuropsychopharmacology*, 35(5), 1129-37.

Frokjaer, Vibe G.; Erik L. Mortensen; Finn Å Nielsen; Steven Haugbol; Lars H. Pinborg; Karen H. Adams; Claus Svarer; Steen G. Hasselbalch; Soeren Holm; Olaf B. Paulson, et al. 2008. "Frontolimbic Serotonin 2a Receptor Binding in Healthy Subjects Is Associated with Personality Risk Factors for Affective Disorder." *Biol Psychiatry*, 63(6), 569-76.

Frydman, C.; C. Camerer; P. Bossaerts and A. Rangel. 2011. "Maoa-L Carriers Are Better at Making Optimal Financial Decisions under Risk." *Proc Biol Sci*, 278(1714), 2053-9.
Gardiner, E.; N. J. Beveridge; J. Q. Wu; V. Carr; R. J. Scott; P. A. Tooney and M. J. Cairns. 2012. "Imprinted Dlk1-Dio3 Region of 14q32 Defines a Schizophrenia-Associated Mirna Signature in Peripheral Blood Mononuclear Cells." *Molecular psychiatry*, 17(8), 827-40.
Gladwell, Malcolm. 2008. *Outliers: The Story of Success*. Penguin UK.
Glaeser, Edward L; David Laibson and Bruce Sacerdote. 2002. "An Economic Approach to Social Capital." *The Economic Journal*, 112(483), F437-F58.
Glatt, Stephen J.; Ming T. Tsuang; Mary Winn; Sharon D. Chandler; Melanie Collins; Linda Lopez; Melanie Weinfeld; Cindy Carter; Nicholas Schork; Karen Pierce, et al. 2012. "Blood-Based Gene Expression Signatures of Infants and Toddlers with Autism." *Journal of the American Academy of Child & Adolescent Psychiatry*, 51(9), 934-44.e2.
Glatt, Stephen J.; Daniel S. Tylee; Sharon D. Chandler; Joel Pazol; Caroline M. Nievergelt; Christopher H. Woelk; Dewleen G. Baker; James B. Lohr; William S. Kremen; Brett T. Litz, et al. 2013. "Blood-Based Gene-Expression Predictors of Ptsd Risk and Resilience among Deployed Marines: A Pilot Study." *American Journal of Medical Genetics Part B: Neuropsychiatric Genetics*, 162(4), 313-26.
Gneezy, U.; K.L. Lleonard and J. A. List. 2009. "Gender Differences in Competition: Evidence from a Matrilineal and a Patriarchal Society." *Econometrica*, 77(5), 1637–64.
Gneezy, Uri; Kenneth L Leonard and John A List. 2009. "Gender Differences in Competition: Evidence from a Matrilineal and a Patriarchal Society." *Econometrica*, 77(5), 1637-64.
Goeree, Jacob K; Charles A Holt and Thomas R Palfrey. 2003. "Risk Averse Behavior in Generalized Matching Pennies Games." *Games and economic behavior*, 45(1), 97-113.
Grant, Simon; Atsushi Kajii and Ben Polak. 2001. "“Third Down with a Yard to Go”: Recursive Expected Utility and the Dixit–Skeath Conundrum." *Economics Letters*, 73(3), 275-86.
Gu, L.; J. Long; Y. Yan; Q. Chen; R. Pan; X. Xie; X. Mao; X. Hu; B. Wei and L. Su. 2013. "Htr2a-1438a/G Polymorphism Influences the Risk of Schizophrenia but Not Bipolar Disorder or Major Depressive Disorder: A Meta-Analysis." *Journal of neuroscience research*, 91(5), 623-33.
Hammerstein, Peter and Edward H Hagen. 2005. "The Second Wave of Evolutionary Economics in Biology." *Trends in Ecology & Evolution*, 20(11), 604-09.
Heinz, A.; D. F. Braus; M. N. Smolka; J. Wrase; I. Puls; D. Hermann; S. Klein; S. M. Grusser; H. Flor; G. Schumann, et al. 2005. "Amygdala-

Prefrontal Coupling Depends on a Genetic Variation of the Serotonin Transporter." *Nat Neurosci*, 8(1), 20-21.
Henrich, J.; R. Boyd; S. Bowles; C. Camerer; E. Fehr; H. Gintis; R. McElreath; M. Alvard; A. Barr; J. Ensminger, et al. 2005. ""Economic Man" in Cross-Cultural Perspective: Behavioral Experiments in 15 Small-Scale Societies." *Behav Brain Sci*, 28(6), 795-815; discussion 15-55.
Henrich, Joseph; Robert Boyd; Samuel Bowles; Colin Camerer; Ernst Fehr; Herbert Gintis and Richard McElreath. 2001. "Cooperation, Reciprocity and Punishment in Fifteen Small-Scale Societies." *American Economic Review*, 91(2), 73-78.
Hey, John D and Chris Orme. 1994. "Investigating Generalizations of Expected Utility Theory Using Experimental Data." *Econometrica: Journal of the Econometric Society*, 1291-326.
Hochard, Jacob and Edward Barbier. 2014. "Market Accessibility and Economic Growth: Insights from a New Dimension of Inequality."
Hofstede, Geert; Gert Jan Hofstede and Michael Minkov. 1991. *Cultures and Organizations: Software of the Mind*. McGraw-Hill London.
Holt, Charles A and Susan K Laury. 2002. "Risk Aversion and Incentive Effects." *American Economic Review*, 92(5), 1644-55.
Hsu, M.; M. Bhatt; R. Adolphs; D. Tranel and C. F. Camerer. 2005. "Neural Systems Responding to Degrees of Uncertainty in Human Decision-Making." *Science*, 310(5754), 1680-3.
Huang, Xuehui; Nori Kurata; Xinghua Wei; Zi-Xuan Wang; Ahong Wang; Qiang Zhao; Yan Zhao; Kunyan Liu; Hengyun Lu; Wenjun Li, et al. 2012. "A Map of Rice Genome Variation Reveals the Origin of Cultivated Rice." *Nature*, 490(7421), 497-501.
Ishii, Keiko. 2013. "Culture and the Mode of Thought: A Review." *Asian Journal of Social Psychology*, 16(2), 123-32.
Kahneman, Daniel and Amos Tversky. 1979. "Prospect Theory: An Analysis of Decision under Risk." *Econometrica: Journal of the Econometric Society*, 263-91.
Kano, M.; T. Mizuno; Y. Kawano; M. Aoki; M. Kanazawa and S. Fukudo. 2012. "Serotonin Transporter Gene Promoter Polymorphism and Alexithymia." *Neuropsychobiology*, 65(2), 76-82.
Karlan, Dean S. 2005. "Using Experimental Economics to Measure Social Capital and Predict Financial Decisions." *American Economic Review*, 1688-99.
Kent, J. M.; J. D. Coplan; O. Mawlawi; J. M. Martinez; S. T. Browne; M. Slifstein; D. Martinez; A. Abi-Dargham; M. Laruelle and J. M. Gorman. 2005. "Prediction of Panic Response to a Respiratory Stimulant by Reduced Orbitofrontal Cerebral Blood Flow in Panic Disorder." *American Journal of Psychiatry*, 162(7), 1379-U2.
Kim, Heejung S and Joni Y Sasaki. 2014. "Cultural Neuroscience: Biology of the Mind in Cultural Contexts." *Annual review of psychology*, 65, 487-514.

Kitayama, S. and A. K. Uskul. 2011. "Culture, Mind, and the Brain: Current Evidence and Future Directions." *Annu Rev Psychol*, 62, 419-49.
Kling, Anders; Tom Mjörndal and Solbritt Rantapää-Dahlqvist. 2013. "Glucocorticoid Treatment Increases Density of Serotonin 5-Ht2a Receptors in Humans." *Psychoneuroendocrinology*, 38(7), 1014-20.
Knack, Stephen and Philip Keefer. 1997. "Does Social Capital Have an Economic Payoff? A Cross-Country Investigation." *The Quarterly journal of economics*, 1251-88.
Knutson, B. and P. Bossaerts. 2007. "Neural Antecedents of Financial Decisions." *J Neurosci*, 27(31), 8174-7.
Knutson, B. and S. M. Greer. 2008. "Anticipatory Affect: Neural Correlates and Consequences for Choice." *Philos Trans R Soc Lond B Biol Sci*, 363(1511), 3771-86.
Kohane, I. S. and V. I. Valtchinov. 2012. "Quantifying the White Blood Cell Transcriptome as an Accessible Window to the Multiorgan Transcriptome." *Bioinformatics*, 28(4), 538-45.
Kometer, M.; A. Schmidt; L. Jancke and F. X. Vollenweider. 2013. "Activation of Serotonin 2a Receptors Underlies the Psilocybin-Induced Effects on Alpha Oscillations, N170 Visual-Evoked Potentials, and Visual Hallucinations." *J Neurosci*, 33(25), 10544-51.
Kreps, David M and Evan L Porteus. 1978. "Temporal Resolution of Uncertainty and Dynamic Choice Theory." *Econometrica: Journal of the Econometric Society*, 185-200.
Kuhnen, C. M. and J. Y. Chiao. 2009. "Genetic Determinants of Financial Risk Taking." *PLoS ONE*, 4(2), e4362.
Kuhnen, C. M.; G. R. Samanez-Larkin and B. Knutson. 2013. "Serotonergic Genotypes, Neuroticism, and Financial Choices." *PLoS ONE*, 8(1), e54632.
Kurian, S. M.; H. Le-Niculescu; S. D. Patel; D. Bertram; J. Davis; C. Dike; N. Yehyawi; P. Lysaker; J. Dustin; M. Caligiuri, et al. 2011. "Identification of Blood Biomarkers for Psychosis Using Convergent Functional Genomics." *Molecular psychiatry*, 16(1), 37-58.
Kuwano, Y.; Y. Kamio; T. Kawai; S. Katsuura; N. Inada; A. Takaki and K. Rokutan. 2011. "Autism-Associated Gene Expression in Peripheral Leucocytes Commonly Observed between Subjects with Autism and Healthy Women Having Autistic Children." *PLoS ONE*, 6(9), e24723.
Le-Niculescu, H.; Y. Balaraman; S. Patel; J. Tan; K. Sidhu; R. E. Jerome; H. J. Edenberg; R. Kuczenski; M. A. Geyer; J. I. Nurnberger, Jr., et al. 2007a. "Towards Understanding the Schizophrenia Code: An Expanded Convergent Functional Genomics Approach." *Am J Med Genet B Neuropsychiatr Genet*, 144(2), 129-58.
Le-Niculescu, H.; S. M. Kurian; N. Yehyawi; C. Dike; S. D. Patel; H. J. Edenberg; M. T. Tsuang; D. R. Salomon; J. I. Nurnberger, Jr. and A. B. Niculescu. 2009. "Identifying Blood Biomarkers for Mood Disorders

Using Convergent Functional Genomics." *Molecular psychiatry*, 14(2), 156-74.
Le-Niculescu, H.; M. J. McFarland; S. Mamidipalli; C. A. Ogden; R. Kuczenski; S. M. Kurian; D. R. Salomon; M. T. Tsuang; J. I. Nurnberger, Jr. and A. B. Niculescu. 2007b. "Convergent Functional Genomics of Bipolar Disorder: From Animal Model Pharmacogenomics to Human Genetics and Biomarkers." *Neurosci Biobehav Rev*, 31(6), 897-903.
Lee, B. T. and B. J. Ham. 2008. "Serotonergic Genes and Amygdala Activity in Response to Negative Affective Facial Stimuli in Korean Women." *Genes Brain Behav*, 7(8), 899-905.
Leibbrandt, Andreas; Uri Gneezy and John A List. 2013. "Rise and Fall of Competitiveness in Individualistic and Collectivistic Societies." *Proceedings of the National Academy of Sciences*, 110(23), 9305-08.
Lerner, Jennifer S; Deborah A Small and George Loewenstein. 2004. "Heart Strings and Purse Strings Carryover Effects of Emotions on Economic Decisions." *Psychological Science*, 15(5), 337-41.
Levitt, Steven D.; John A. List and David H. Reiley. 2010. "What Happens in the Field Stays in the Field: Exploring Whether Professionals Play Minimax in Laboratory Experiments." *Econometrica*, 78(4), 1413-34.
Loewenstein, G.; S. Rick and J. D. Cohen. 2008. "Neuroeconomics." *Annu Rev Psychol*, 59, 647-72.
Lopez-Figueroa, A. L.; C. S. Norton; M. O. Lopez-Figueroa; D. Armellini-Dodel; S. Burke; H. Akil; J. F. Lopez and S. J. Watson. 2004. "Serotonin 5-Ht1a, 5-Ht1b, and 5-Ht2a Receptor Mrna Expression in Subjects with Major Depression, Bipolar Disorder, and Schizophrenia." *Biol Psychiatry*, 55(3), 225-33.
Manolio, T. A.; F. S. Collins; N. J. Cox; D. B. Goldstein; L. A. Hindorff; D. J. Hunter; M. I. McCarthy; E. M. Ramos; L. R. Cardon; A. Chakravarti, et al. 2009. "Finding the Missing Heritability of Complex Diseases." *Nature*, 461(7265), 747-53.
McDermott, Rose; James H Fowler and Oleg Smirnov. 2008. "On the Evolutionary Origin of Prospect Theory Preferences." *Journal of Politics*, 70(2), 335-50.
McDonald, A. J. and F. Mascagni. 2007. "Neuronal Localization of 5-Ht Type 2a Receptor Immunoreactivity in the Rat Basolateral Amygdala." *Neuroscience*, 146(1), 306-20.
McKelvey, Richard D and Thomas R Palfrey. 1995. "Quantal Response Equilibria for Normal Form Games." *Games and economic behavior*, 10(1), 6-38.
McKelvey, Richard D.; Andrew M. McLennan and Theodore L. Turocy. 2014. "Gambit: Software Tools for Game Theory, Version 14.1.0."
Mehta, D.; M. Gonik; T. Klengel; M. Rex-Haffner; A. Menke; J. Rubel; K. B. Mercer; B. Putz; B. Bradley; F. Holsboer, et al. 2011. "Using Polymorphisms in Fkbp5 to Define Biologically Distinct Subtypes of

Posttraumatic Stress Disorder: Evidence from Endocrine and Gene Expression Studies." *Arch Gen Psychiatry*, 68(9), 901-10.
Meltzer, H. Y. 2012. "Serotonergic Mechanisms as Targets for Existing and Novel Antipsychotics." *Handb Exp Pharmacol*, (212), 87-124.
Mestre, T. A.; M. Zurowski and S. H. Fox. 2013. "5-Hydroxytryptamine 2a Receptor Antagonists as Potential Treatment for Psychiatric Disorders." *Expert Opin Investig Drugs*, 22(4), 411-21.
Montague, R.P. 2007. "Neuroeconomics: A View from Neuroscience." *Funct Neurol*, 22(4), 219-34.
Muguruza, C.; J. L. Moreno; A. Umali; L. F. Callado; J. J. Meana and J. Gonzalez-Maeso. 2013. "Dysregulated 5-Ht(2)a Receptor Binding in Postmortem Frontal Cortex of Schizophrenic Subjects." *Eur Neuropsychopharmacol*, 23(8), 852-64.
Munier, Bertrand and Costin Zaharia. 2002. "High Stakes and Acceptance Behavior in Ultimatum Bargaining." *Theory and Decision*, 53(3), 187-207.
Navarro, A. 2009. "Genoeconomics: Promises and Caveats for a New Field." *Ann N Y Acad Sci*, 1167, 57-65.
Netzer, Nick. 2009. "Evolution of Time Preferences and Attitudes toward Risk." *The American Economic Review*, 937-55.
O'Neill, Barry. 1987. "Nonmetric Test of the Minimax Theory of Two-Person Zerosum Games." *Proceedings of the National Academy of Sciences*, 84(7), 2106-09.
Ochs, Jack. 1995. "Games with Unique, Mixed Strategy Equilibria: An Experimental Study." *Games and economic behavior*, 10(1), 202-17.
Palacios-Huerta, Ignacio. 2003. "Professionals Play Minimax." *The Review of Economic Studies*, 70(2), 395-415.
Palacios ‐ Huerta, Ignacio and Oscar Volij. 2008. "Experientia Docet: Professionals Play Minimax in Laboratory Experiments." *Econometrica*, 76(1), 71-115.
Papastergiadis, Nikos. 2013. *The Turbulence of Migration: Globalization, Deterritorialization and Hybridity*. John Wiley & Sons.
Piva, F.; M. Giulietti; B. Nardi; C. Bellantuono and G. Principato. 2010. "An Improved in Silico Selection of Phenotype Affecting Polymorphisms in Slc6a4, Htr1a and Htr2a Genes." *Hum Psychopharmacol*, 25(2), 153-61.
Prelec, Drazen. 1998. "The Probability Weighting Function." *ECONOMETRICA-EVANSTON ILL-*, 66, 497-528.
Preuss, U. W.; G. Koller; B. Bondy; M. Bahlmann and M. Soyka. 2001. "Impulsive Traits and 5-Ht2a Receptor Promoter Polymorphism in Alcohol Dependents: Possible Association but No Influence of Personality Disorders." *Neuropsychobiology*, 43(3), 186-91.
Putnam, Robert. 1993. "Making Democracy Work." *Princeton University Press, Princeton NJ*.
Putnam, Robert D. 2000. *Bowling Alone: The Collapse and Revival of American Community*. Simon and Schuster.

Qian, Nancy. 2008. "Missing Women and the Price of Tea in China: The Effect of Sex-Specific Earnings on Sex Imbalance." *The Quarterly journal of economics*, 123(3), 1251-85.
Rabin, Matthew. 1993. "Incorporating Fairness into Game Theory and Economics." *The American Economic Review*, 1281-302.
____. 1998. "Psychology and Economics." *Journal of economic literature*, 36(1), 11-46.
Roberts, Brent W; Nathan R Kuncel; Rebecca Shiner; Avshalom Caspi and Lewis R Goldberg. 2007. "The Power of Personality: The Comparative Validity of Personality Traits, Socioeconomic Status, and Cognitive Ability for Predicting Important Life Outcomes." *Perspectives on Psychological Science*, 2(4), 313-45.
Rollins, B.; M. V. Martin; L. Morgan and M. P. Vawter. 2010. "Analysis of Whole Genome Biomarker Expression in Blood and Brain." *Am J Med Genet B Neuropsychiatr Genet*, 153B(4), 919-36.
Rosenthal, Robert W; Jason Shachat and Mark Walker. 2003. "Hide and Seek in Arizona." *International Journal of Game Theory*, 32(2), 273-93.
Roth, Alvin E; Vesna Prasnikar; Masahiro Okuno-Fujiwara and Shmuel Zamir. 1991. "Bargaining and Market Behavior in Jerusalem, Ljubljana, Pittsburgh, and Tokyo: An Experimental Study." *The American Economic Review*, 1068-95.
Ruan, Jianqing; Zhuan Xie and Xiaobo Zhang. 2014. "Does Rice Farming Shape Individualism and Innovation? A Response to Talhelm Et Al.(2014)."
Rustichini, A.; C. DeYoung; J. Anderson and S. Burks. 2012. "Toward the Integration of Personality Theory and Decision Theory in the Explanation of Economic and Health Behavior."
Seck, Papa Abdoulaye; Aliou Diagne; Samarendu Mohanty and Marco CS Wopereis. 2012. "Crops That Feed the World 7: Rice." *Food Security*, 4(1), 7-24.
Shelton, RC; E Sanders-Bush; DH Manier and DA Lewis. 2009. "Elevated 5-Ht 2a Receptors in Postmortem Prefrontal Cortex in Major Depression Is Associated with Reduced Activity of Protein Kinase A." *Neuroscience*, 158(4), 1406-15.
Singelis, Theodore M. 1994. "The Measurement of Independent and Interdependent Self-Construals." *Personality and Social Psychology Bulletin*, 20(5), 580-91.
Slonim, Robert and Alvin E Roth. 1998. "Learning in High Stakes Ultimatum Games: An Experiment in the Slovak Republic." *Econometrica*, 569-96.
Smith, Ryan M; Audrey C Papp; Amy Webb; Cara L Ruble; Leanne M Munsie; Laura K Nisenbaum; Joel E Kleinman; Barbara K Lipska and Wolfgang Sadee. 2013. "Multiple Regulatory Variants Modulate

Expression of 5-Hydroxytryptamine 2a Receptors in Human Cortex." *Biol Psychiatry*, 73(6), 546-54.
Sokol-Hessner, P.; C. F. Camerer and E. A. Phelps. 2013. "Emotion Regulation Reduces Loss Aversion and Decreases Amygdala Responses to Losses." *Soc Cogn Affect Neurosci*, 8(3), 341-50.
Sokol-Hessner, P.; M. Hsu; N. G. Curley; M. R. Delgado; C. F. Camerer and E. A. Phelps. 2009. "Thinking Like a Trader Selectively Reduces Individuals' Loss Aversion." *Proceedings of the National Academy of Sciences of the United States of America*, 106(13), 5035-40.
Starmer, Chris. 2000. "Developments in Non-Expected Utility Theory: The Hunt for a Descriptive Theory of Choice under Risk." *Journal of economic literature*, 332-82.
Sullivan, P. F.; C. Fan and C. M. Perou. 2006. "Evaluating the Comparability of Gene Expression in Blood and Brain." *Am J Med Genet B Neuropsychiatr Genet*, 141B(3), 261-8.
Takahashi, H. 2012. "Monoamines and Assessment of Risks." *Curr Opin Neurobiol*, 22(6), 1062-7.
Talhelm, T.; X. Zhang; S. Oishi; C. Shimin; D. Duan; X. Lan and S. Kitayama. 2014. "Large-Scale Psychological Differences within China Explained by Rice Versus Wheat Agriculture." *Science*, 344(6184), 603-8.
Tang, Y.; A. Lu; R. Ran; B. J. Aronow; E. K. Schorry; R. J. Hopkin; D. L. Gilbert; T. A. Glauser; A. D. Hershey; N. W. Richtand, et al. 2004. "Human Blood Genomics: Distinct Profiles for Gender, Age and Neurofibromatosis Type 1." *Brain Res Mol Brain Res*, 132(2), 155-67.
Tom, S. M.; C. R. Fox; C. Trepel and R. A. Poldrack. 2007. "The Neural Basis of Loss Aversion in Decision-Making under Risk." *Science*, 315(5811), 515-8.
Tversky, Amos and Daniel Kahneman. 1992. "Advances in Prospect Theory: Cumulative Representation of Uncertainty." *Journal of Risk and uncertainty*, 5(4), 297-323.
Tylee, D. S.; D. M. Kawaguchi and S. J. Glatt. 2013. "On the Outside, Looking In: A Review and Evaluation of the Comparability of Blood and Brain "-Omes"." *Am J Med Genet B Neuropsychiatr Genet*, 162(7), 595-603.
Uddin, M.; A. E. Aiello; D. E. Wildman; K. C. Koenen; G. Pawelec; R. de Los Santos; E. Goldmann and S. Galea. 2010. "Epigenetic and Immune Function Profiles Associated with Posttraumatic Stress Disorder." *Proceedings of the National Academy of Sciences of the United States of America*, 107(20), 9470-5.
Ursini, G.; V. Bollati; L. Fazio; A. Porcelli; L. Iacovelli; A. Catalani; L. Sinibaldi; B. Gelao; R. Romano; A. Rampino, et al. 2011. "Stress-Related Methylation of the Catechol-O-Methyltransferase Val158 Allele Predicts Human Prefrontal Cognition and Activity." *J Neurosci*, 31(18), 6692-98.

van Ijzendoorn, M. H.; M. J. Bakermans-Kranenburg; J. Belsky; S. Beach; G. Brody; K. A. Dodge; M. Greenberg; M. Posner and S. Scott. 2011. "Gene-by-Environment Experiments: A New Approach to Finding the Missing Heritability." *Nat Rev Genet*, 12(12), 881; author reply 81.
Vandesompele, J.; K. De Preter; F. Pattyn; B. Poppe; N. Van Roy; A. De Paepe and F. Speleman. 2002. "Accurate Normalization of Real-Time Quantitative Rt-Pcr Data by Geometric Averaging of Multiple Internal Control Genes." *Genome Biol*, 3(7), RESEARCH0034.
Vázquez, Delia M.; Charles R. Neal Jr; Paresh D. Patel; Niko Kaciroti and Juan F. López. 2012. "Regulation of Corticoid and Serotonin Receptor Brain System Following Early Life Exposure of Glucocorticoids: Long Term Implications for the Neurobiology of Mood." *Psychoneuroendocrinology*, 37(3), 421-37.
von Neumann, John and Oscar Morgenstern. 1944. *Theory of Games and Economic Behavior*. Princeton: Princeton University Press.
Walker, Mark and John Wooders. 2001. "Minimax Play at Wimbledon." *American Economic Review*, 1521-38.
Weisstaub, N. V.; M. Zhou; A. Lira; E. Lambe; J. Gonzalez-Maeso; J. P. Hornung; E. Sibille; M. Underwood; S. Itohara; W. T. Dauer, et al. 2006. "Cortical 5-Ht2a Receptor Signaling Modulates Anxiety-Like Behaviors in Mice." *Science*, 313(5786), 536-40.
Winkielman, Piotr; Kent C Berridge and Julia L Wilbarger. 2005. "Unconscious Affective Reactions to Masked Happy Versus Angry Faces Influence Consumption Behavior and Judgments of Value." *Personality and Social Psychology Bulletin*, 31(1), 121-35.
Winstanley, Catharine A; David EH Theobald; Jeffrey W Dalley; Jeffrey C Glennon and Trevor W Robbins. 2004. "5-Ht2a and 5-Ht2c Receptor Antagonists Have Opposing Effects on a Measure of Impulsivity: Interactions with Global 5-Ht Depletion." *Psychopharmacology*, 176(3-4), 376-85.
Woelk, C. H.; A. Singhania; J. Perez-Santiago; S. J. Glatt and M. T. Tsuang. 2011. "The Utility of Gene Expression in Blood Cells for Diagnosing Neuropsychiatric Disorders." *Int Rev Neurobiol*, 101, 41-63.
Wooders, John. 2010. "Does Experience Teach? Professionals and Minimax Play in the Lab." *Econometrica*, 78(3), 1143-54.
Yi, Z.; Z. Li; S. Yu; C. Yuan; W. Hong; Z. Wang; J. Cui; T. Shi and Y. Fang. 2012. "Blood-Based Gene Expression Profiles Models for Classification of Subsyndromal Symptomatic Depression and Major Depressive Disorder." *PLoS ONE*, 7(2), e31283.
Zhong, S.; R. Chark; R. P. Ebstein and S. H. Chew. 2012. "Imaging Genetics for Utility of Risks over Gains and Losses." *Neuroimage*, 59(1), 540-6.

Zhong, S.; S. Israel; H. Xue; R. P. Ebstein and S. H. Chew. 2009a. "Monoamine Oxidase a Gene (Maoa) Associated with Attitude Towards Longshot Risks." *PLoS ONE*, 4(12), e8516.
Zhong, S.; S. Israel; H. Xue; P. C. Sham; R. P. Ebstein and S. H. Chew. 2009b. "A Neurochemical Approach to Valuation Sensitivity over Gains and Losses." *Proc Biol Sci*, 276(1676), 4181-8.