Online Appendix for:

An analysis of heritability in preferences using behavioral models of decision-making

Nathan Kettlewell*
University of Technology Sydney

Agnieszka Tymula†
University of Sydney

Hong Il Yoo‡
Loughborough University

*University of Technology Sydney, Economics Discipline Group, Sydney, NSW, Australia. Email: Nathan.Kettlewell@uts.edu.au

†School of Economics, University of Sydney, Sydney, 2006 NSW, Australia. Email: agnieszka.tymula@sydney.edu.au

‡Loughborough Business School, Loughborough University, Leicestershire LE11 3TU, United Kingdom. Email: h.i.yoo@lboro.ac.uk

Appendix A. Sample likelihood function

This appendix summarizes the algebraic structure of our sample likelihood functions. To convey the main ideas without excessive notational cluttering, we focus on an illustrative example that considers structural estimation of utility curvature parameter α_{sn} under EUT. Continuing with the notation defined in Section 4 of the main text, this theory of risk preferences is derived by assuming that decision weight ω_{sn} in the risk preference experiment equals the objective probability of 0.5 for all sibling $s \in \{1, 2\}$, twin pair $n \in \{1, 2, \cdots, N\}$ and choice task $t \in \{1, 2, \cdots, T\}$.

Let c_{snt} denote a binary indicator that equals 1 if sibling s of pair n selected Option A in task t and 0 if Option B. Conditional on structural parameter α_{sn} and behavioral noise parameter μ, the likelihood of this choice observation can be specified as

$$\begin{aligned} P_{snt}[\alpha_{sn}, \mu] &= \Lambda[\Delta V_{snt}[\alpha_{sn}]/\mu_{snt}]^{c_{snt}} \Lambda[-\Delta V_{snt}[\alpha_{sn}]/\mu_{snt}]^{(1-c_{snt})} \text{ and} \\ \mu_{snt} &= (U[M_{A,snt}; \alpha_{sn}] - U[0; \alpha_{sn}])\mu \end{aligned} \tag{A1}$$

where $\Delta V_{snt}[\cdot] = V_{A,snt}[\cdot] - V_{B,snt}[\cdot]$ denotes an expected utility difference, which is derived by evaluating the BSU index functions in equation (7) at $\omega_{sn} = 0.5$; $\Lambda[\cdot]$ is the standard logistic distribution function; and other notations are defined in Section 4.

Our empirical approach considers structural parameter α_{sn} as a draw from an S_B distribution, which in turn is generated from an ACE model. We can represent this chain of modeling assumptions by writing $\alpha_{sn} = r[\gamma, A_{sn}, C_{sn}, E_{sn}]$, where function $r[\cdot]$ denotes a mapping of the ACE components to the structural parameter.[1]

As presented in the main text, the ACE model imposes constraints on the patterns of between-sibling correlations in the latent factors A_{sn}, C_{sn}, and E_{sn}. Specifically, the unique environmental factor E_{sn} is uncorrelated between two siblings of the same twin pair; the common environmental factor C_n displays perfect positive correlation, implying that $C_{1n} = C_{2n} = C_n$; and the additive genetic factor A_{sn} displays perfect or imperfect positive correlation, depending on whether the twins are identical (MZ) or non-identical (DZ). Additionally, the model assumes that the marginal distribution of each factor is a zero-mean normal with a variance common to both siblings. To summarize these assumptions, we use $f[\boldsymbol{A}_n|\sigma_A^2, \rho]$ denote the bivariate normal density for $\boldsymbol{A}_n = \{A_{1n}, A_{2n}\}$, where σ_A^2 refers to the common variance of A_{1n} and A_{2n}; and ρ refers to the correlation between A_{1n} and A_{2n}, which varies between MZ twins ($\rho = 1$) and DZ twins ($\rho = 0.5$). Similarly, we use $f[\boldsymbol{C}_n|\sigma_C^2, 1]$ and $f[\boldsymbol{E}_n|\sigma_E^2, 0]$ to denote the bivariate normal densities for $\boldsymbol{C}_n = \{C_{1n}, C_{2n}\}$

[1] To state $r[\cdot]$ explicitly, suppose that α_{sn} falls into interval (κ_L, κ_U). Then, $r[\gamma, A_{sn}, C_{sn}, E_{sn}] = \kappa_L + (\kappa_U - \kappa_L)\Lambda[\gamma + A_{sn} + C_{sn} + E_{sn}]$.

and $\boldsymbol{E}_n = \{E_{1n}, E_{2n}\}$.

Conditional on the latent ACE factors and the behavioral noise parameter μ, the likelihood of choice observations on twin pair n can be specified as

$$l_n[\boldsymbol{A}_n, \boldsymbol{C}_n, \boldsymbol{E}_n, \mu] = \prod_{s=1}^{2} \prod_{t=1}^{T} P_{snt}\big[r[\gamma, A_{sn}, C_{sn}, E_{sn}], \mu\big]. \tag{A2}$$

As is typical in the estimation of random parameter models, this twin pair's contribution to the sample likelihood function can then be derived by integrating out the latent factors as follows

$$\begin{aligned} L_n[\gamma, \sigma_A^2, \sigma_C^2, \sigma_E^2, \mu] = \int\int\int l_n[\boldsymbol{A}_n, \boldsymbol{C}_n, \boldsymbol{E}_n, \mu] \times \\ f[\boldsymbol{A}_n|\sigma_A^2, \rho] f[\boldsymbol{C}_n|\sigma_C^2, 1] f[\boldsymbol{E}_n|\sigma_E^2, 0] d\boldsymbol{A}_n d\boldsymbol{C}_n d\boldsymbol{E}_n \end{aligned} \tag{A3}$$

where the genetic correlation, ρ, is set to 1 for MZ twins and 0.5 for DZ twins.

To estimate primitive parameters in the argument list of $L_n[\cdot]$, we can maximize a sample log-likelihood function which adds up the natural log of this pair-level likelihood across all twin pairs in the sample: $\sum_{n=1}^{N} \ln\big[L_n[\cdot]\big]$. In practice, since this sample log-likelihood function does not have an analytic expression, we maximize its simulated analogue instead. Our likelihood evaluator uses 2,000 draws from shuffled Halton sequences to simulate each pair's likelihood contribution.

The logic of this illustrative example extends to other models of decision-making. In a nutshell, for each structural parameter in the analysis, one must include a distinct set of ACE parameters: $\gamma, \sigma_A^2, \sigma_C^2, \text{and} \sigma_E^2$. Consequently, the number of integrals in each equation above is doubled if one is to estimate the BSU model of risk preferences, as this model imposes the ACE structure on the decision weight ω_n in addition to the power coefficient α_n. It is quadrupled if one is to jointly estimate the BSU model of risk preferences with the QH discounting model of time preferences, which requires the ACE structure to be placed on β_n and δ_n as well as α_n and ω_n. Allowing the behavioral noise parameter μ to vary from model to model does not affect the number of integrals because it is a primitive parameter to be estimated directly rather than a random coefficient to be integrated out.

Appendix B. Meta analysis

B.1 Identifying studies for inclusion

To identify studies for inclusion, we searched Google Scholar using the following search terms: ”risk attitudes/preferences”, ”risk aversion”, ”time preferences”, ”intertemporal choice”, ”temporal discounting”, ”delay discounting”, ”present bias” + ”heritability”, ”genetic basis”, ”twin studies”. We supplemented the results from this search with by adding additional studies that we were aware of. We also searched additional databases such as PsycINFO but did not find any further studies to include. The studies we identified are summarized in Tables B.1 and B.2.

Table B.1: Literature summary of the heritability of risk attitudes

Study	Measurement method		MZ/DZ	F/M	Registry	Age
Cesarini et al. (2009)	B (I)	Certainty equivalent determined by six choices between a 50/50 gamble for SEK100 and varying sure payoffs	307/135	20/80	Swedish Twin Registry	
	B (NI)	Proportion of £1m invested (options: 0, 200k, 400k, 600k, 800k, 1m)	319/139	20/80		
	S	Dohmen et al. (2005) (10-point scale)	317/139	20/80		
Anokhin et al. (2009)	B (I)	Number of pumps in BART	82/71	0/100	US	12.5 (0.21)
	B (I)	Number of pumps in BART	87/49	100/0		12.5 (0.21)
	B (I)	Number of pumps in BART	41/41	0/100		14.6 (0.64)
	B (I)	Number of pumps in BART	57/24	100/0		14.6 (0.64)
Zhong et al. (2009)	B (I)	Ranking of 3 options: (1) 50/50 of getting 40 or 0, (2) 20 for sure, (3) 15 for sure (high risk taking if (1) was ranked highest, medium if (2), low if (3))	158/62	50/50	China	30 (14.63)
Zyphur et al. (2009)	B (NI)	Composite score based on: (1) choice between $2k for sure, 50% chance of $5k, and 20% chance of $15k, (2) choice between 3 retirement funds ranging from safe to risky, (3) hypothetical trade of salary for company stock (3 options, more risky=more stocks).	111/89	0/100	Minnesota Twin Registry	36.7 (1.12)
Simonson & Sela (2011)	B (NI)	% of safe choices in lottery choice (gain domain)	110/70	78/22	North Carolina Twin Registry	MZ: 46.6 DZ:49
	B (NI)	% of safe choices in lottery choice (loss domain)	110/70	78/22		
Harden et al. (2017)	B (NI)	Count of plays in Iowa Gambling task	153/284	48/52	Texas Twin Project	15.9 (1.4)
	B (NI)	Number of pumps in BART	153/284	48/52		
	B (NI)	% failed stops at crossroads in Stoplight Task	153/284	48/52		
	S	Risk perceptions (28 items on 7 activities)	153/284	48/52		

Beauchamp et al. (2017)	B (NI)	Four ordinal categories based on a hypothetical choice between a sure payoff and a 50/50 gamble to decide the lifetime monthly salary	1000/1083	54/46	Swedish Twin Registry	R=52-67
	S	“Are you generally a person who is fully prepared to take risks or do you try to avoid taking risks?” (10-point scale)	1128/1200	54/46		
	S	11 response categories (10-point scale)	1134/1212	54/46		
Nicolaou & Shane (2020)	B (NI)	Proportion of £100k invested (options: 0, 20k, 40k, 60k, 80k, 100k)	1898/1344	92/8	TwinsUK Registry	
	B (NI)	Choice between 3 lotteries (Zyphur et al.., 2009)	1898/1344	92/8		
	S	“Are you generally a person who is fully prepared to take risks or do you try to avoid taking risks?” (10-point scale)	1898/1344	92/8		
	S	Domain-specifc: financial matters, car driving, leisure and sports, health, career (10-point scale)	1898/1344	92/8		
Le et al. (2010)	S	“How much risk are you willing to tolerate when deciding how to invest your money?” (10-point scale)	867/1008	57/43	Australian Twin Registry Younger Cohort	37.7

Table B.2: Literature summary of the heritability of time preferences

Study	Measurement method		MZ/DZ	F/M	Registry	Age
Anokhin et al. (2011)	B (I)	$7 today or $10 in 7 days (categorical)	169/203	48/52	US	12.5 (0.21)
	B (I)	$7 today or $10 in 7 days (categorical)	N=606	48/52		14.6 (0.24)
Sparks et al. (2014)	B (I)	$7 today or $10 in 7 days	239/159	50/50	Minnesota Twin Registry	$\sim$ 17 y.o.
Cesarini et al. (2012)	B (NI)	Number of times immedate option was chosen (money today or more money in a week, 3 items)	1150/2362	54/46	Swedish Twin Registry	R=51-66
Isen et al. (2014)	B (NI)	$0.5-$10 now or $10 after a delay of 1, 2, 10, 30, 180 or 365 days (AUC)	148/97	45/55	Minnesota Twin Registry	15.1 (0.55)
Anokhin et al. (2015)	B (NI)	138 choices between $X now or $100 in Y days (AUC)	50/39	51/49	US	16.6 (0.26)
	B (NI)	138 choices between $X now or $100 in Y days (AUC)	113/125	51/49		18.5 (0.21)
	B (NI)	138 choices between $X now or $100 in Y days (hyperbolic k)	50/38	51/49		16.6 (0.26)
	B (NI)	138 choices between $X now or $100 in Y days (hyperbolic k)	108/124	51/49		18.5 (0.21)
Harden et al. (2017)	B (NI)	Indifference point in smaller sooner and larger later choices (staircase approach)	153/284	48/52	Texas Twin Project	15.9 (1.4)
	S	UPPS Impulsivity Scale (45 items, 4 dimensions)				
	S	Future Orientation Scale (15 items, 3 dimensions)				
Hubler (2018)	S	"Would you describe yourself as a patient or impatient person?" (11-point scale)	703/775	56/44	German TwinLife	17.1 (5.1)

B.2 Effect sizes and standard errors

If a study measured preferences using more than one instrument in the same sample, we use only one estimate. In the case of behavioral preferences, we prioritize estimates from incentivized elicitations and those that provide the most precise estimates.

Two major challenges arise when summarising estimates from AC(D)E models. These are differences in the models that are estimated, and inconsistent reporting of standard errors.

Some papers only report estimates from the best fitting model (often an AE model, with C constrained to zero), while others estimate the full ACE specification. Our preferred approach is to use the full ACE estimates to avoid constraining C, so we use the estimates from the complete ACE model whenever they are reported. In the remaining cases, we use the estimates of from the best-fitting model among those that were reported. In the few papers that estimated an ADE model, in slight abuse of notation, what we refer to as A is in fact an aggregation of the additive (A) and dominant (D) genetic effects. One concern with our adopted approach is that studies that only report AE estimates may get higher weight than they should, since constraining C will often lower the standard error for A%. We address this concern with sensitivity analysis below.

For conventional meta-analysis we need the standard error for each study; however, it is a common convention in twin studies to only report confidence intervals. In situations where the confidence interval is symmetric, the standard error can be recovered if we assume that it was constructed as $\pm 1.96 \times SE$. But in some studies the confidence intervals are constructed to respect the fact that variance shares are bounded [0,1], so are not symmetric. Details on how confidence intervals were constructed were frequently missing in the studies we reviewed. We suspect that in many cases likelihood-based intervals (see Neale and Miller, 1997) were used, since this is the default in popular open-source R programs used for twin studies.

Table B.3 shows, for each study included in our analyses, the point estimate, the standard error we used, and how that standard error was obtained.

Table B.3: Estimates and standard errors used in meta-analyses

Study	A% (SE)	E% (SE)	Details
		Behavioral risk preference studies	
Cesarini et al. (2009)	0.16 (0.077)	0.75 (0.056)	$SE = \max[UL - Est., Est. - LL]/1.96$ using the reported 95% credible intervals. The intervals were approximately symmetric.
Anokhin et al. (2009)*, M 12 y.o.	0.28 (0.071)	0.72 (0.071)	$SE = \max[UL - Est., Est. - LL]/1.96$ using the reported 95% confidence intervals. The intervals were symmetric.

Anokhin et al. (2009)*, F 12 y.o.	0.17 (0.087)	0.83 (0.087)	$SE = \max[UL - Est., Est. - LL]/1.96$ using the reported 95% confidence intervals. The intervals were approximately symmetric (slight asymmetry possibly due to rounding).
Zhong et al. (2009)	0.54 (0.226)	0.46 (0.111)	$SE = \max[UL - Est., Est. - LL]/1.96$ using the reported 95% confidence intervals. The intervals were not symmetric.
Zyphur et al. (2009)#	0.63 (0.25)	0.37 (0.290)	Reported SE for A%. SE not reported for the E variance share, but was reported for the E path coefficient (e). Since E=e^2, we used the delta method ($SE_e \times f'(E)$).
Simonson & Sela (2011)*	0.33 (0.158)	0.67 (0.158)	$SE = \max[UL - Est., Est. - LL]/1.96$ using the reported 95% confidence intervals. The intervals were approximately symmetric, but not close enough to be explained by rounding.
Beauchamp et al. (2017)#	0.42 (0.226)	0.58 (0.036)	Reported SE for E. For A%, because an ADE model was estimated this was A+D. SE is calculated as $\sqrt{SE_A^2 + SE_D^2}$ using the reported SE_A and SE_D.
Nicolaou & Shane (2020)*	0.25 (0.031)	0.75 (0.031)	$SE = \max[UL - Est., Est. - LL]/1.96$ using the reported 95% confidence intervals. The intervals were approximately symmetric, but not close enough to be explained by rounding.
		Stated risk preference studies	
Cesarini et al. (2009)	0.29 (0.077)	0.65 (0.051)	$SE = \max[UL - Est., Est. - LL]/1.96$ using the reported 95% credible intervals. The intervals were approximately symmetric.
Beauchamp et al. (2017)#	0.36 (0.176)	0.65 (0.031)	Reported SE for E. For A%, because an ADE model was estimated this was A+D. SE is calculated as $\sqrt{SE_A^2 + SE_D^2}$ using the reported SE_A and SE_D.
Nicolaou & Shane (2020)	0.22 (0.066)	0.78 (0.046)	$SE = \max[UL - Est., Est. - LL]/1.96$ using the reported 95% confidence intervals. The A% intervals were approximately symmetric, but not close enough to be explained by rounding. The E interval was symmetric.
Le et al. (2010)*	0.23 (0.033)	0.77 (0.033)	SE for A% obtained by dividing the estimate by the reported t-statistic. The regression approach used in this paper did not directly estimate E, so we set its SE equal to the SE for A%.
		Behavioral time preference studies	

Anokhin et al. (2011)*	0.30 (0.097)	0.70 (0.097)	$SE = \max[UL - Est., Est. - LL]/1.96$ using the reported 95% confidence intervals. The intervals were approximately symmetric, but not close enough to be explained by rounding.
Sparks et al. (2014)	0.37 (0.189)	0.51 (0.107)	$SE = \max[UL - Est., Est. - LL]/1.96$ using the reported 95% confidence intervals. The intervals were approximately symmetric, but not close enough to be explained by rounding.
Cesarini et al. (2012)	0.18 (0.092)	0.75 (0.056)	$SE = \max[UL - Est., Est. - LL]/1.96$ using the reported 95% confidence intervals. The intervals were approximately symmetric but not by construction (obtained using likelihood approach).
Anokhin et al. (2015)*	0.62 (0.056)	0.38 (0.056)	$SE = \max[UL - Est., Est. - LL]/1.96$ using the reported 95% confidence intervals. The intervals were approximately symmetric, but not close enough to be explained by rounding.

Note: *Estimates from an AE model. #Estimates from an ADE model.

An alternative to using the available information about parameter uncertainty reported in the papers is to approximate standard errors using a standardized approach. For example, in Polderman et al. (2015) the authors transform variance shares into Fisher Z-values with the approximate standard errors depending only on the sample size, conduct the meta-analysis and then back-transform the estimates at the end. This approach can also be used on the MZ/DZ correlations with heritability estimated using Falconer's formula, rather than the usual SEM or multi-level regression approach; however, we do not do this since the Falconer approach does not compare neatly to our own analysis of deep parameters.

We explored the possibility of using transformed Z-values for our study but ultimately rejected this due to unsatisfactory weights given to the different studies. Using the Fisher approach, our meta-estimate for behavioral risk preference is 36% (95% CI [23%,48%]), which is larger than our preferred estimate of 25% [20%,30%]. This difference is driven by the fact that the studies received nearly identical weights using the Fisher approach, even though some studies were much less precise than others. For example, the study by Zyphur et al. (2009) (A%=63% with 95% CI [15%,100%] in the original study) received a weight of 0.96% in our preferred approach, reflecting the large degree of uncertainty, compared to 12.16% in the Fisher approach. In contrast, Nicolaou and Shane (2020) (A%=30% with 95% CI [19%,30%] in the original study) received a weight of 64.21% in our preferred approach, reflecting its far greater precision than other studies, compared to 13.67% in the Fisher approach – a weighting only slightly larger than that given to Zyphur et al. (2009).

B.3 Sensitivity

One concern with using the reported parameter uncertainty details is that A% estimates will be more precise in studies that only report AE model estimates because constraining the C component reduces uncertainty. To gauge whether this is likely to meaningfully affect our results in practice, we conducted a bounding exercise by scaling the standard errors in studies that use the AE model by a (relatively large) factor of 1.5. For behavioral risk preference, our meta-estimate is identical but with a slightly larger confidence interval as expected (25% [18%,32%]). Our estimates are also nearly identical for stated risk (25% [18%,31%]) and for behavioral time preference (37% [16%,59%]), differing by only one percentage point from what we report in the paper. We therefore conclude that any bias from using the AE estimates is likely to be small.

B.4 Additional meta-analysis results

Figure B.1: Meta-analysis of the genetic role (A) in stated risk aversion

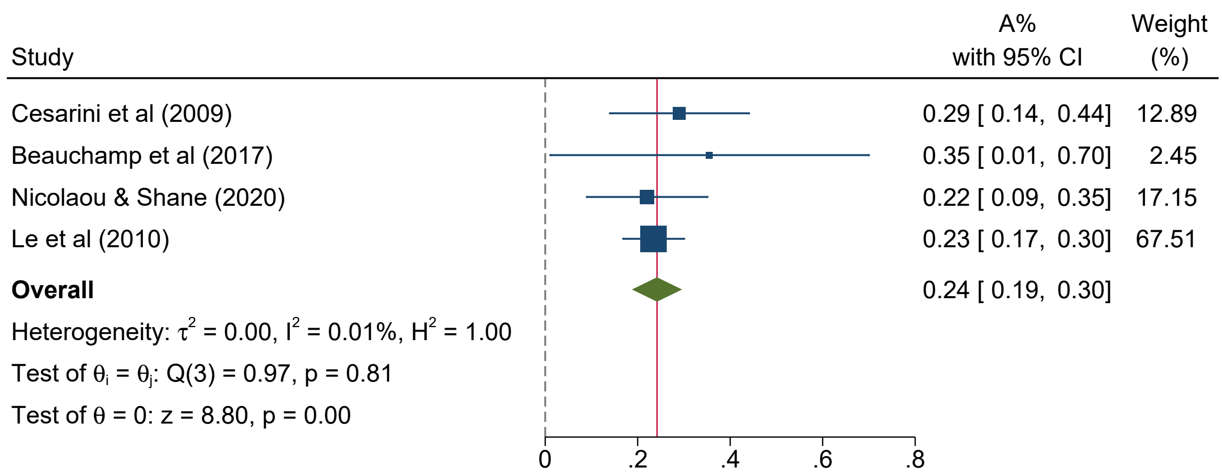
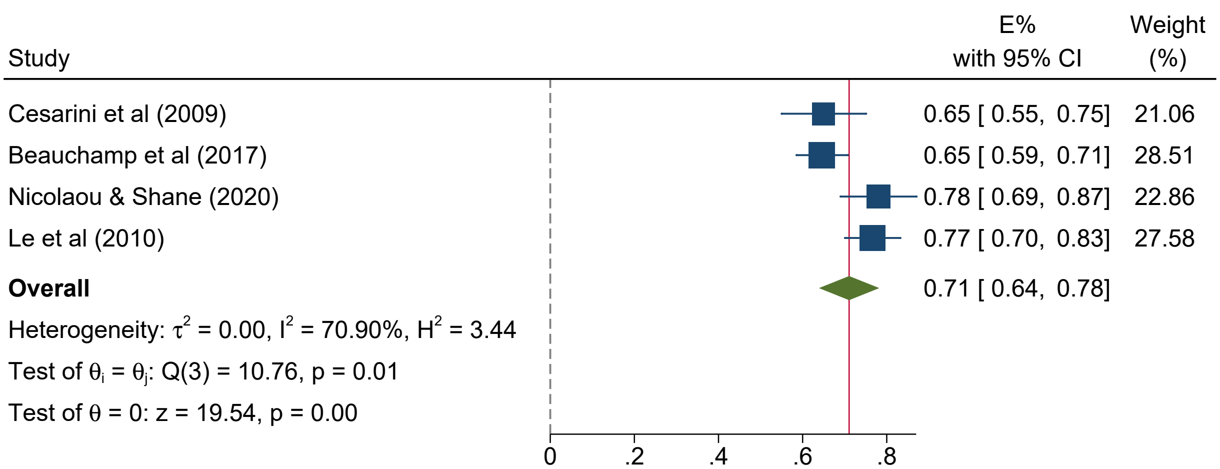


Figure B.2: Meta-analysis of the unique environment (E) role in stated risk aversion



Appendix C. Additional results

Table C.1: Descriptive statistics by zygosity

	Mean MZ	SD MZ	Mean DZ	SD DZ	Diff	P-val
Age	44.03	12.89	46.29	12.57	2.26	0.058
Male	0.14	0.35	0.25	0.43	0.10	0.002
Twin years together	22.38	5.40	20.40	3.91	-1.98	0.000
Born in Australia	0.87	0.34	0.90	0.30	0.03	0.260
Lives in a city	0.65	0.48	0.66	0.48	0.01	0.759
Couple	0.65	0.48	0.69	0.46	0.04	0.304
Household members	4.51	1.83	4.44	1.84	-0.08	0.577
Dependent children	1.89	1.42	2.02	1.52	0.13	0.289
University degree	0.59	0.49	0.60	0.49	0.01	0.816
Employed	0.86	0.35	0.84	0.37	-0.02	0.409
Retired	0.08	0.27	0.09	0.28	0.01	0.822
Income	1256.90	703.32	1321.91	719.97	65.01	0.246
Financially secure	3.16	0.76	3.18	0.75	0.02	0.748
Long-term health condition	0.22	0.41	0.19	0.39	-0.03	0.316
COVID-19 worry	2.82	2.70	2.81	2.66	-0.01	0.956
COVID-19 prob	10.92	15.54	9.57	13.30	-1.35	0.177
COVID-19 mortality	14.04	20.34	13.51	19.07	-0.53	0.719
COVID-19 job loss	0.07	0.25	0.06	0.24	0.00	0.848
COVID-19 reduced income	0.13	0.33	0.14	0.34	0.01	0.660
COVID-19 work home	0.35	0.48	0.35	0.48	-0.01	0.806
COVID-19 reduced hours	0.14	0.34	0.13	0.34	-0.01	0.831
Num. COVID-19 positive friends	1.88	2.56	1.73	2.48	-0.15	0.371
Risk MPL1 num safe	8.03	3.29	8.32	3.35	0.29	0.228
Risk MPL2 num safe	5.17	2.11	5.34	2.13	0.17	0.238
Uncertainty MPL1 num safe	8.51	3.34	8.69	3.40	0.18	0.449
Uncertainty MPL2 num safe	5.41	2.19	5.52	2.27	0.11	0.488
Time MPL1 num sooner	3.82	3.31	3.48	3.24	-0.34	0.130
Time MPL2 num sooner	3.49	2.99	3.38	3.02	-0.11	0.605
Time MPL3 num sooner	4.00	3.36	3.88	3.39	-0.12	0.605
Time MPL4 num sooner	3.99	3.30	3.86	3.37	-0.13	0.569

Note: Descriptive statistics based on samples of 802 MZ twins (401 pairs) and 318 DZ twins (159 pairs). See Appendix Table C.2 for detailed variable definitions.

Table C.2: Variable descriptions

Variable	Definition	MZ obs.	DZ obs.
Age	Age at last birthday	802	318
Male	= 1 if male	802	318
Twin years together	How many years (including your childhood) lived with your twin	802	318
Australia born	= 1 if born in Australia	802	318
Lives in a city	= 1 if currently live in a major city (Sydney, Melbourne, Brisbane, Adelaide, Perth, Canberra)	795	317
Couple	= 1 if married or in a defacto relationship	800	314
Household members	How many people live in your household	799	315
Dependent children	Number of dependent children	766	310
University degree	= 1 if highest level of education obtained is a university degree	802	318
Employed	= 1 if worked any time in the last 7 days or if had a job but did not work in the last 7 days due to holidays, sickness or any other reason	802	318
Retired	= 1 if currently retired from the workforce	802	318
Income	Average usual weekly own income in the last month using midpoint value for the following categories: \$1-\$149, \$150-\$299, \$300-\$399, \$400-\$499, \$500-\$649, \$650-\$799, \$800-\$999, \$1,000-\$1,249, \$1,250-\$1,499, \$1,500-\$1,749, \$1,750-\$1,999, \$2,000-\$2,999, \$3,000 or more (coded as \$3000). Negative or nil coded as missing.	692	275
Financially secure	Given your current needs and financial responsibility, would you say that you and your family are: = 1 if Poor, = 2 if Just getting along, = 3 if Comfortable, = 4 if Very comfortable, = 5 if Prosperous.	802	318
Long-term health condition	= 1 if has a long-term health condition, impairment or disability that has lasted more than 6 months	800	318
COVID-19 worry	Worry or concern about contracting COVID-19 on a scale of 1 to 10	798	318
COVID-19 prob	Probability participant believes they will get COVID-19 in the next 3 months	796	315
COVID-19 mortality	If you do get COVID-19, what is the percent chance you will die from it?	795	317

COVID-19 job loss	= 1 if experienced job loss due to COVID-19	802	318
COVID-19 reduced income	= 1 if experienced reduction in income due to COVID-19	802	318
COVID-19 work home	= 1 if experienced working from home due to COVID-19	802	318
COVID-19 reduced hours	= 1 if experienced a reduction in working hours due to COVID-19	802	318
Num. COVID-19 positive friends	How many relatives or close friends have tested positive for COVID-19	799	318
Risk MPL1 num safe	Number of safe choices in MPL task 1 (known probabilities)	802	318
Risk MPL2 num safe	Number of safe choices in MPL task 2 (known probabilities)	802	318
Uncertainty MPL1 num safe	Number of safe choices in MPL task 1 (unknown probabilities)	802	318
Uncertainty MPL2 num safe	Number of safe choices in MPL task 2 (unknown probabilities)	802	318
Time MPL1 num sooner	Number of sooner choices in MPL task 1	802	318
Time MPL2 num sooner	Number of sooner choices in MPL task 2	802	318
Time MPL3 num sooner	Number of sooner choices in MPL task 3	802	318
Time MPL4 num sooner	Number of sooner choices in MPL task 4	802	318

Table C.3: Correlations between number of years living with twin and absolute difference between twin pairs in elicited preference variables

	Correlation	P-val
Risk MPL1 num safe	-0.063	0.054
Risk MPL2 num safe	-0.049	0.113
Uncertainty MPL1 num safe	-0.021	0.514
Uncertainty MPL2 num safe	-0.029	0.364
Time MPL1 num sooner	-0.026	0.376
Time MPL2 num sooner	-0.05	0.104
Time MPL3 num sooner	-0.005	0.889
Time MPL4 num sooner	-0.024	0.432

Table C.4: Pearson correlations by zygosity in elicited preference variables

	MZ twins			DZ twins		
	Correlation	Lower CI	Upper CI	Correlation	Lower CI	Upper CI
Risk MPL1 num safe	.068	-.001	.137	.171	.063	.276
Risk MPL2 num safe	.048	-.022	.116	.107	-.003	.214
Uncertainty MPL1 num safe	.168	.1	.235	.079	-.031	.188
Uncertainty MPL2 num safe	.261	.195	.324	.153	.043	.258
Time MPL1 num sooner	.159	.091	.226	-.004	-.114	.106
Time MPL2 num sooner	.186	.119	.252	-.007	-.117	.103
Time MPL3 num sooner	.25	.184	.314	-.028	-.137	.083
Time MPL4 num sooner	.263	.197	.326	-.002	-.112	.108

Note: Confidence intervals are constructed using Fisher's transformation.

Table C.5: ACE share decomposition results: additional models

Model	A	C	E
	Risk preferences		
MPL1	0.02 (0.00, 0.08)	0.09 (0.02, 0.18)	0.90 (0.78, 0.97)
MPL2	0.02 (0.00, 0.11)	0.06 (0.01, 0.15)	0.93 (0.78, 0.99)
Panel	0.00 (0.00, 0.08)	0.10 (0.02, 0.23)	0.90 (0.75, 0.97)
EUT	0.04 (0.00, 0.14)	0.00 (0.00, 0.05)	0.95 (0.84, 0.99)
ST α	0.60 (0.55, 0.65)	0.01 (0.00, 0.03)	0.39 (0.35, 0.43)
ST ω^{risk}	0.74 (0.66, 0.80)	0.00 (0.00, 0.02)	0.26 (0.20, 0.33)
STQH α	0.19 (0.14, 0.24)	0.02 (0.00, 0.06)	0.79 (0.75, 0.82)
STQH ω^{risk}	0.00 (0.00, 0.15)	0.57 (0.40, 0.69)	0.42 (0.29, 0.54)
	Uncertainty preferences		
MPL1	0.11 (0.02, 0.26)	0.05 (0.00, 0.20)	0.83 (0.70, 0.91)
MPL2	0.19 (0.05, 0.37)	0.07 (0.00, 0.25)	0.73 (0.60, 0.82)
Panel	0.00 (0.00, 0.19)	0.17 (0.07, 0.27)	0.83 (0.61, 0.91)
EUT	0.21 (0.13, 0.29)	0.02 (0.00, 0.13)	0.77 (0.64, 0.85)
ST ω^{unc}	0.73 (0.68, 0.77)	0.00 (0.00, 0.02)	0.27 (0.23, 0.32)
STQH ω^{unc}	0.20 (0.10, 0.33)	0.39 (0.26, 0.51)	0.41 (0.22, 0.60)
	Ambiguity preferences		
MPL1	0.05 (0.00, 0.16)	0.00 (0.00, 0.03)	0.95 (0.83, 1.00)
MPL2	0.05 (0.00, 0.19)	0.00 (0.00, 0.02)	0.95 (0.80, 1.00)
Panel	0.24 (0.01, 0.52)	0.07 (0.00, 0.46)	0.69 (0.42, 0.77)
EUT	0.00 (0.00, 0.08)	0.05 (0.02, 0.08)	0.95 (0.86, 0.98)
ST $\omega^{risk} - \omega^{unc}$	0.73 (0.68, 0.77)	0.00 (0.00, 0.02)	0.27 (0.23, 0.32)
STQH $\omega^{risk} - \omega^{unc}$	0.13 (0.07, 0.25)	0.45 (0.35, 0.54)	0.41 (0.29, 0.54)
	Time preferences (Delay aversion)		
MPL1	0.14 (0.06, 0.25)	0.00 (0.00, 0.02)	0.86 (0.75, 0.94)
MPL2	0.16 (0.07, 0.26)	0.00 (0.00, 0.04)	0.84 (0.73, 0.92)
MPL3	0.22 (0.14, 0.32)	0.00 (0.00, 0.01)	0.78 (0.68, 0.86)
MPL4	0.24 (0.15, 0.34)	0.00 (0.00, 0.01)	0.76 (0.66, 0.85)
Panel	0.01 (0.00, 0.14)	0.13 (0.07, 0.18)	0.87 (0.74, 0.91)
EXP	0.00 (0.00, 0.08)	0.19 (0.15, 0.21)	0.81 (0.72, 0.83)
EUTEXP	0.00 (0.00, 0.00)	0.04 (0.03, 0.05)	0.96 (0.95, 0.97)
QH	0.06 (0.05, 0.06)	0.00 (0.00, 0.00)	0.94 (0.93, 0.95)
EUTQH	0.00 (0.00, 0.00)	0.18 (0.16, 0.20)	0.82 (0.80, 0.84)
STQH	0.25 (0.20, 0.30)	0.03 (0.01, 0.06)	0.73 (0.64, 0.79)
	Time preferences (Present bias)		
MPL1-MPL3	0.06 (0.00, 0.18)	0.01 (0.00, 0.07)	0.94 (0.80, 0.99)
MPL2-MPL4	0.03 (0.00, 0.29)	0.05 (0.00, 0.24)	0.92 (0.67, 0.97)
Panel	0.11 (0.00, 0.39)	0.01 (0.00, 0.14)	0.88 (0.57, 0.97)
QH	0.14 (0.07, 0.21)	0.04 (0.01, 0.10)	0.81 (0.71, 0.87)

EUTQH	0.05 (0.01, 0.13)	0.06 (0.02, 0.13)	0.88 (0.80, 0.94)
STQH	0.32 (0.01, 0.53)	0.00 (0.00, 0.49)	0.68 (0.37, 0.89)

Note: ST represents the Source Theory specification discussed in Section 4.2, with a common utility function across risk and uncertainty tasks. STQH extends this to also jointly estimate time preferences with a quasi-hyperbolic discount function. See Figures 5–9 for further details on other models.

Appendix D. Survey instruments

Table D.1: Risk preference tasks

MPL1		MPL2	
Sure thing	50/50 chance	Sure thing	50/50 chance
$2	$30/$0	$2.50	$25/$0
$4	$30/$0	$5	$25/$0
$6	$30/$0	$7.50	$25/$0
$8	$30/$0	$10	$25/$0
$10	$30/$0	$12.50	$25/$0
$12	$30/$0	$15	$25/$0
$14	$30/$0	$17.50	$25/$0
$16	$30/$0	$20	$25/$0
$18	$30/$0	$22.50	$25/$0
$20	$30/$0	$25	$25/$0
$22	$30/$0		
$24	$30/$0		
$26	$30/$0		
$28	$30/$0		
$30	$30/$0		

Table D.2: Time preference tasks

MPL1 (MPL 3)		MPL2 (MPL4)	
Now (4 weeks)	8 weeks (12 weeks)	Now (12 weeks)	6 weeks (18 weeks)
$15	$15.50	$13	$13.50
$15	$16.50	$13	$15
$15	$17.50	$13	$16.50
$15	$18.50	$13	$18
$15	$19.50	$13	$19.50
$15	$20.50	$13	$21
$15	$21.50	$13	$22.50
$15	$22.50	$13	$24
$15	$23.50	$13	$25.50
$15	$24.50	$13	$27

References

Neale, M. C. and M. B. Miller (1997). The use of likelihood-based confidence intervals in genetic models. *Behavior genetics 27*, 113–120.

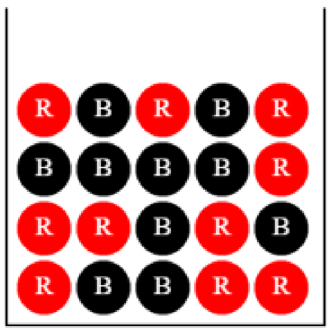
Nicolaou, N. and S. Shane (2020). Common genetic effects on risk-taking preferences and choices. *Journal of Risk and Uncertainty 59*(3), 261–279.

Polderman, T. J., B. Benyamin, C. A. De Leeuw, P. F. Sullivan, A. Van Bochoven, P. M. Visscher, and D. Posthuma (2015). Meta-analysis of the heritability of human traits based on fifty years of twin studies. *Nature Genetics 47*(7), 702–709.

Zyphur, M. J., J. Narayanan, R. D. Arvey, and G. J. Alexander (2009). The genetics of economic risk preferences. *Journal of Behavioral Decision Making 22*(4), 367–377.

Figure D.1: Example: Risk preference (risks known) task instructions

There is a box with 20 balls in it, like the one below.



Half of the balls in the box are **red** and the other half are **black**. In other words, there is an equal chance that a ball randomly drawn from the box by the computer will be either **red** or **black**.

Your task is to choose whether you would prefer a fixed amount of money for sure "the sure thing", or whether you'd prefer for the computer to draw one of the balls from the box at random. If this ball is of the winning colour, you will receive $30. If it is not of the winning colour, you receive nothing.

There are 15 questions for you to work through on the next page.

If this task is chosen for payment, the computer will randomly select one of the 15 questions.

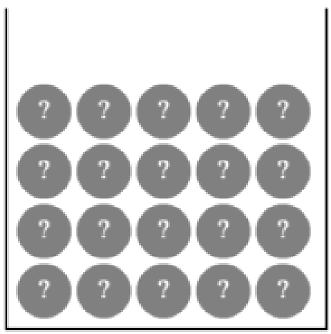
Before you make your choices, please select whether you would like the winning colour to be black or red.

As my winning colour, I select:

Figure D.2: Example: Risk preference (risks unknown) task instructions

There is a box with 20 balls in it. Each of the balls in the box is either **red** or **black**.

This time, you do not know the ratio of red and black balls in the box. It has been decided by a random number generator. The balls could all be red, they could all be black, or there could be any combination of red and black balls.



Your task is to choose whether you would prefer a fixed amount of money for sure "the sure thing", or whether you'd prefer for the computer to draw one of the balls from the box at random. If this ball is of the winning colour, you will receive $30. If it is not of the winning colour, you receive nothing.

There are 15 questions for you to work through on the next page.

If this task is chosen for payment, the computer will randomly select one of the 15 questions.

Before you make your choices, please select whether you would like the winning colour to be black or red.

As my winning colour, I select:

Figure D.3: Example: Risk preference MPL choice display

Select your preferred choice for each row below.

	Sure thing	Box gamble
\$2 for sure (sure thing) or \$30 if Red (box gamble)		
\$4 for sure (sure thing) or \$30 if Red (box gamble)		
\$6 for sure (sure thing) or \$30 if Red (box gamble)		
\$8 for sure (sure thing) or \$30 if Red (box gamble)		
\$10 for sure (sure thing) or \$30 if Red (box gamble)		
\$12 for sure (sure thing) or \$30 if Red (box gamble)		
\$14 for sure (sure thing) or \$30 if Red (box gamble)		
\$16 for sure (sure thing) or \$30 if Red (box gamble)		
\$18 for sure (sure thing) or \$30 if Red (box gamble)		
\$20 for sure (sure thing) or \$30 if Red (box gamble)		
\$22 for sure (sure thing) or \$30 if Red (box gamble)		
\$24 for sure (sure thing) or \$30 if Red (box gamble)		
\$26 for sure (sure thing) or \$30 if Red (box gamble)		
\$28 for sure (sure thing) or \$30 if Red (box gamble)		
\$30 for sure (sure thing) or \$30 if Red (box gamble)		

Figure D.4: Example: Time preference instructions and MPL choice display

We want to know which payment option you prefer in each row of the four tables below. In each table the amount of money varies between dates, as well as the timing of when the payment will be made.

If this task is chosen for payment, we will randomly select one row from one of the tables and pay you according to which option you chose.

Be aware that for each row, the date of the payment will be X weeks after you and your twin complete the survey. For example, when we say the payment will be 'now', that means we will arrange the transfer as soon as you and your twin complete the survey (processed within 10 days). When we say 'in 8 weeks', that means 8 weeks after you and your twin complete the survey (and so on).

Pleased select your preferred payment in each row.

	Paid now	Paid in 8 weeks
$15 now or $15.50 in 8 weeks	○	○
$15 now or $16.50 in 8 weeks	○	○
$15 now or $17.50 in 8 weeks	○	○
$15 now or $18.50 in 8 weeks	○	○
$15 now or $19.50 in 8 weeks	○	○
$15 now or $20.50 in 8 weeks	○	○
$15 now or $21.50 in 8 weeks	○	○
$15 now or $22.50 in 8 weeks	○	○
$15 now or $23.50 in 8 weeks	○	○
$15 now or $24.50 in 8 weeks	○	○