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ASSESSING INDIVIDUAL RISK ATTITUDES USING FIELD DATA FROM LOTTERY GAMES

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Abstract—We use information from the television game show with the highest guaranteed average payoff in the United States, *Hoosier Millionaire*, to analyze risktaking in a high-stakes experiment. We characterize gambling decisions under alternative assumptions about contestant behavior and preferences, and derive testable restrictions on individual risk attitudes based on this characterization. We then use an extensive sample of gambling decisions to estimate distributions of risk-aversion parameters consistent with the theoretical restrictions and revealed preferences. We find that although most contestants display risk-averse preferences, the extent of the risk aversion implied by our estimates varies substantially with the stakes involved in the different decisions.

I. Introduction

A series of recent studies (Rabin, 2000a, 2000b; Rabin and Thaler, 2001) have pointed out the inadequacy of expected-utility theory to provide proper characterization of risk aversion when monetary stakes are small. The basic contention of this criticism is that the concavity of the utility function would have to be so pronounced to explain small-stake risk aversion that this same utility function would imply absurd levels of risk aversion for large stakes. Rabin (2000b) concludes that "Expected-utility theory seems to be a useful and adequate model of risk aversion for many purposes, such as understanding large-stakes insurance . . . ," but "is manifestly not close to the right explanation of risk attitudes over modest stakes . . . ."

A number of studies have attempted to characterize individual risk aversion under large stakes using expected-utility theory. Experiments by Binswanger (1981) and Kachelmeier and Shehata (1992) face subjects with decisions involving small nominal stakes that are large relative to the subjects' wealth. Their findings are mixed: whereas Binswanger's subjects exhibit more risk-averse behavior as stakes are increased, Kachelmeier and Shehata conclude that "the effects of monetary payoffs are real, albeit subtle, and are in need of further study." Unfortunately, the inherent limitations of rewards in experimental studies make it difficult to get more robust conclusions about risktaking in large-stakes settings.

A second group of papers analyzes risktaking behavior using information from natural experiments involving large

Received for publication June 21, 1999. Revision accepted for publication January 7, 2002.

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We thank Gabriella Bucci, Larry Samuelson, Richard Sheehan, various workshop participants, and two anonymous referees for numerous comments. Part of this project was completed while Tenorio visited the Management and Strategy Department at Northwestern University. He is thankful for their hospitality. Trish and Marcos Delgado provided superb research assistance. All errors or omissions are the authors'.

The Review of Economics and Statistics, February 2003, 85(1): 218–225

stakes. Gertner (1993) uses betting decisions from the bonus round of the television game show *Card Sharks*, and concludes that individuals exhibit a small degree of risk aversion. Metrick (1995) and Hersch and McDougall (1997) analyze field data from wagering decisions on the television game shows *Final Jeopardy!* and *Illinois Instant Riches*, respectively, and find that contestants display behavior that is statistically indistinguishable from risk neutrality. In contrast, Beetsma and Schotman (2001) conclude that contestants in the Dutch television show *LINGO* exhibit substantial risk aversion.

In this paper we use information from the television show *Hoosier Millionaire* to gain additional insight into the behavior of individuals in high-stakes situations. Although this show has undergone a number of regime changes, the current regime is representative of the typical decision a contestant faces: she may either (a) take a sure $100,000, or (b) play a game in which she gets $150,000, $200,000, 1,000,000, or $0, each with equal probability. If she draws $150,000 or $200,000, she may stop playing and keep the prize, or continue drawing from the remaining alternatives until she either decides to stop, or draws $0 or $1,000,000. Prizes are not cumulative.

We believe, for various reasons, that the structure of the decision problems in *Hoosier Millionaire* provides us with a very appealing natural experiment to study individual decisions under risk. First, unlike previous game studies, the realization of the risky prospect is the outcome of a very simple probability process, where no subjectivity or skills are involved.[1] Second, the stakes are larger than those in previous studies, thus allowing a more proper characterization of risk aversion using expected-utility theory. Finally, our data comprise a time series of games involving several regime changes, which allows us to study the sensitivity of individual behavior across various gambles.

Our approach to analyzing risk aversion differs significantly from previous game-based studies. Exogenous wagers and lack of variation in the gambles prevent us from estimating risk-aversion parameters using regression techniques. Instead, we use the sample properties of the decisions in the different regimes of *Hoosier Millionaire* to estimate the parameters of the distribution of risk-aversion coefficients in the contestant population. In addition, unlike previous studies, we explicitly allow for various degrees of contestant rationality in our estimation.

Our results show that most individuals behave in a way consistent with risk aversion, and as noted in recent studies, the implied degree of risk aversion varies largely with the stakes of the decision. In fact, our estimates imply substantial risk aversion for gambles comparable to those in *Hoosier Millionaire*, while also implying near-risk-neutrality for smaller gambles of similar structure. We also show that the effect of different behavioral traits on decisions and risk aversion is only evident under large stakes.

[1] Both *Card Sharks* and *Illinois Instant Riches* involve nontrivial probability calculations, and *Final Jeopardy* and *LINGO* involve subjective assessments of one's (or other players') ability to solve a puzzle or answer a question.

II. A Brief History of *Hoosier Millionaire*

The Hoosier Lottery's weekly television show, *Hoosier Millionaire*, first aired on October 28, 1989. Since its inception, each show has involved six contestants chosen randomly from a pool of entries submitted by people playing a scratch-off ticket game. All contestants participate in the first of two phases played on each show. In phase I, all six contestants play a series of purely random draw games. The contestant who amasses the most cash wins and proceeds to phase II; the remaining five contestants leave the show. All six contestants keep the cash and prizes accumulated in phase I.

Four regimes have governed phase II of *Hoosier Millionaire*. In regime 1, the phase I winner has the option of choosing one of four numbers randomly associated with the dollar amounts $50,000, $100,000, and $1,000,000, and a consolation prize of $25,000. If the contestant draws $1 million, she wins that amount, paid out in 10 equal annual payments, and the game is over. If the contestant draws $50,000 or $100,000, she can keep that amount or give it up and make another choice among the remaining alternatives. She continues until she chooses to stop, wins the $1 million, or draws the consolation prize.

In October of 1990, the two intermediate amounts offered in the gamble changed from $50,000 and $100,000 to $100,000 and $200,000. All other features remained the same. We call this regime 2.

In February of 1992, more changes were made to phase II. First, the lowest amount attainable in the initial drawing changed from $100,000 to $150,000. Second, the consolation prize went down from $25,000 to 1,000 scratch-off lottery tickets with a purchase price of $1 each. Finally, lottery officials changed the payment of the $1 million prize to twenty annual payments of $50,000. We call this regime 3.

Rules currently governing phase II of *Hoosier Millionaire* were instituted in February of 1994. According to Pat Traub, the lottery's acting deputy director, these changes offer ". . . the highest guaranteed prize of any game show in the nation . . ." and were made to ". . . enhance the show's entertainment value." Two revisions were made. First, a contestant is now automatically endowed with a guaranteed $100,000 prize. She may then decide to keep that amount and walk away from the show, or give it up and choose one of the four numbers just as in regime 3. The other change involved extending the period of time over which the $1,000,000 prize is paid out from twenty to twenty-five years.[2] We call this regime 4.

[2] This change, not widely publicized by the Lottery Commission, became a heated point of contention in the 1994 Indiana state elections.

III. Analytical Issues

In analytical terms, the problem a *Hoosier Millionaire* contestant faces is one of sequential decisions with no recall. This means that the outcome of the first decision may give the contestant the option to continue playing, but once a continuation decision is made at any stage, the status quo is no longer available. In a problem like this, the optimal decisions follow from using a dynamic programming (or backward induction) technique. This means starting at the final decision node, assessing the values of continuing and stopping at that stage, and then factoring in these values when making decisions at the previous stage(s). This procedure is equivalent to finding the subgame-perfect equilibrium in a game against nature.

In analyzing the optimal strategy for each regime, we consider the following behavioral hypotheses:

***Full Rationality* (FR).** A contestant performs backward induction at each decision node, and discounts the $1,000,000 prize according to the annuity system.[3]

***Bounded Rationality 1* (BR1).** Same as FR, but no discounting is applied to the $1,000,000 prize.

***Bounded Rationality 2* (BR2).** Contestants do not perform backward induction at every decision node, that is, they do not take into account the value of the option to continue playing the game, and evaluate each lottery as a simple rather than a sequentially compounded lottery. Annuities are discounted.

***Bounded Rationality 3* (BR3).** Same as BR2, but annuities are not discounted.

Our bounded-rationality scenarios are motivated by biases observed in decision settings comparable to our problem. Empirical and experimental evidence suggests that low or even negative discounting is common in decisions involving evaluation of income streams over time (BR1, BR3). Loewenstein and Prelec (1991), Loewenstein and Thaler (1989), and Gigliotti and Sopher (1997) note that most subjects prefer a more constant and spread-out stream of income over a strictly decreasing pattern of payments.[4,5]

There is also extensive evidence that individuals fail to perform backward induction in sequential decision environments (BR2, BR3). Carbone and Hey (1998) report a series of decision-making experiments where individuals do not apply Bellman's principle of optimality. Similarly, Camerer et al. (1993) show that subjects do not reason backward in simple alternating-offers bargaining experiments. Instead, most subjects base their decision on current-round payoffs.[6]

Figures 1 and 2 show the game trees associated with regimes 3 and 4 of *Hoosier Millionaire*. We subsequently analyze optimal decisions under each of the behavioral hypotheses outlined above.

A. *Risk Neutrality*

If decisions depend solely on expected values at each decision node, simple calculations show that:

1. Boundedly rational contestants who do not discount annuities (BR1 and BR3) always choose the gamble over the sure prospect. Here, the $1,000,000 prize makes the gambles' expected values very large across the board, even when contestants do not backward-induct.
2. If contestants discount annuities (FR and BR2), gambling may become unattractive as discounting increases. Table 1 shows the discount rates that make a contestant indifferent between gambling and keeping the sure prospect at the various decision nodes. As shown, for sufficiently low discount rates ($r < 10.014\%$), it is optimal to gamble in any regime at any decision node for both the FR and BR2 contestant types. As discounting increases, some of the gambles' expected values fall below the sure prospects. In regimes 1 and 2, discount rates must be very high (above 22%) to discourage individuals from gambling. This is because the $1 million annuity payments are only spread across 10 years and the consolation prize is substantial ($25,000). In regimes 3 and 4, where annuities are paid over 20–25 years and the consolation prize is only $1,000, lower discount rates may induce individuals to take on various gambles.

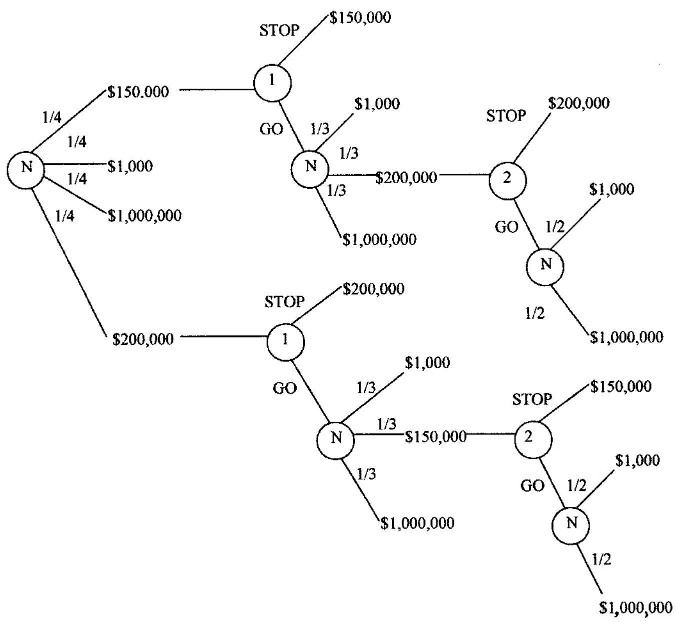
[3] All earnings are taxable. Given the amounts at stake, as long as marginal tax rates are constant over the annuity payments' horizon, decisions should be tax-neutral. We also assume a constant inflation rate over the annuity horizon. Thus our discount rates may be interpreted as real discount rates.

[4] A further possibility is that contestants are unaware of the annuity system, or that their decision frames are affected by the fact that $1 million winners are presented with a large symbolic check for that amount.

[5] A variety of other decision problems involving time-delayed payoffs, but not streams of payoffs, actually show that individuals may overdiscount future payoffs. However, financial companies openly advertise their readiness to convert lottery annuity payments into lump-sum payoffs at discount rates in the 8%–10% range. Thus, overdiscounting appears unlikely in our problem.

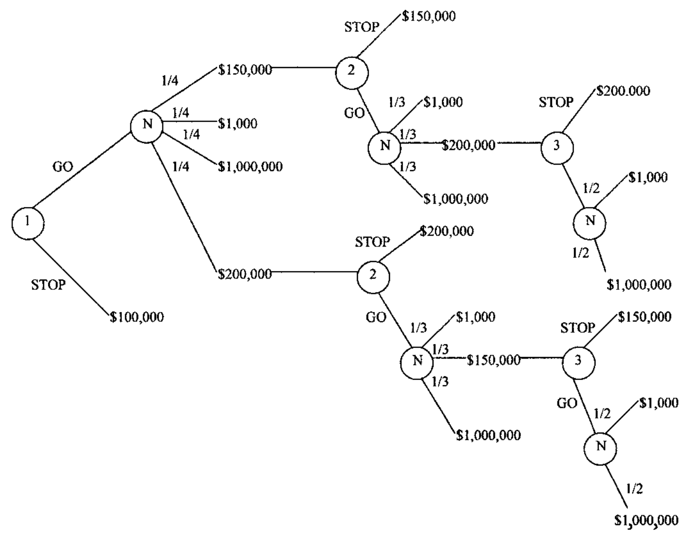
[6] The authors conducted an experiment to gain insight into this issue. The *Hoosier Millionaire* regime 4 decision problem was given as a final exam question in two different courses: first-year MBA Microeconomics and senior-level Risk Management and Insurance. Whereas the MBA students had been exposed to the concept of backward induction, seniors were mostly unfamiliar with it. Our results show that 8 (8.9%) of 90 MBA students and 7 (11.7%) of 60 seniors used backward induction to solve this problem.

FIGURE 1.—REGIME 3



(1) *N* stands for nature; ① and ② represent relevant subgames.
(2) All payments are lump sum except for $1,000,000, which is paid as a 20-year annuity due.

FIGURE 2.—REGIME 4



(1) *N* stands for nature; ①, ②, and ③ represent relevant subgames.
(2) All payments are lump sum except for $1,000,000, which is paid as a 25-year annuity.

B. *Risk Aversion*[7]

To make our results comparable with those of previous studies, we assume that *Hoosier Millionaire* contestants display one of the following two types of preferences:

Constant Absolute Risk Aversion **(CARA).** These preferences, which imply increasing relative risk aversion, are often assumed in studies of individual decision-making. Their generic utility representation is

$$U(W) = -e^{-aW}, \tag{1}$$

where W is the individual's wealth, a is the coefficient of absolute risk aversion, and aW is the coefficient of relative risk aversion. This formulation is convenient because it allows one to calculate absolute risk-aversion coefficients without any wealth information.

Constant Relative Risk Aversion **(CRRA).** These preferences, which imply decreasing absolute risk aversion, are commonly used in macro and asset-pricing studies. Their generic utility representation is

$$U(W) = \frac{W^{1-b}}{1-b}, \tag{2}$$

where W is the individual's wealth, b is the coefficient of relative risk aversion, and b/W is the coefficient of absolute risk aversion. Since this formulation implies that risk aversion depends on wealth, we must know something about that variable to make meaningful inferences. Given lack of comprehensive wealth information, we make alternative

TABLE 1.—DISCOUNT RATES THAT MAKE A RISK-NEUTRAL CONTESTANT INDIFFERENT BETWEEN TAKING AND NOT TAKING THE GAMBLE

	Rate (%)			
Regime	Fully Rational Contestants in Subgame 1	Boundedly Rational-2 Contestants in Subgame 1	Fully Rational Contestants in Subgame 2	Fully Rational Contestants in Subgame 3
1.1	>10.0	>10.0	1.33268	N.a.
1.2	1.33268	0.79588	>10.0	N.a.
2.1	1.33268	>10.00	0.33699	N.a.
2.2	0.33699	0.22315	1.33268	N.a.
3.1	0.19388	0.24749	0.12897	N.a.
3.2	0.12897	0.10722	0.19388	N.a.
4.0	0.25039	4.44444	N.a.	N.a.
4.1	N.a.	N.a.	0.14892	0.10014
4.2	N.a.	N.a.	0.10014	0.14892

Each regime is indexed by the value of the contestant's first draw. A .1 (.2) extension denotes an initial draw equal to the higher (lower) of the two intermediate dollar prizes. Fully rational contestants perform backward induction at each decision node of the tree, whereas boundedly-rational-2 contestants do not perform backward induction (that is, they ignore the option value of continuing to play the game). Both fully rational and boundedly-rational-2 contestants fully discount annuity payments. N.a. = nonapplicable.

[7] It is well known that expected-utility theory fails to account for some empirical regularities in decision-making under uncertainty. The most important two violations relate to the decision-makers' (a) asymmetric evaluations of gains and losses, and (b) use of decision weights instead of probabilities. The decisions we analyze are such that (a) is absent because there are no losses, and the influence of (b) should be minimal due to the simple probability structure of the gambles. In addition, the recent papers by Rabin (2000a, 2000b), and Rabin and Thaler (2001) conclude that risk-aversion results based on expected-utility theory are most accurate when they pertain to decisions involving large stakes, such as those in our games. Thus, we feel comfortable staying within the expected-utility framework.

TABLE 2.—RISK-AVERSION PARAMETERS THAT YIELD EQUAL EXPECTED UTILITIES FROM TAKING AND NOT TAKING THE GAMBLE

Panel A: Constant Absolute Risk Aversion (CARA) Utility Function

	FR			BR1	BR2			BR3
Regime	$r = 10\%$	$r = 20\%$	$r = 30\%$	$r = 0\%$	$r = 10\%$	$r = 20\%$	$r = 30\%$	$r = 0\%$
1.1	2.7726	2.7726	2.7725	2.7726	4.2303	4.2303	4.2303	4.2303
1.2	0.9209	0.9069	0.8760	0.9240	2.7726	2.7726	2.7725	2.7726
2.1	0.9209	0.9069	0.8760	0.9240	1.3432	1.3410	1.3335	1.3435
2.2	0.3349	0.2357	0.0760	0.3825	0.01849	0.0434	−0.1757	0.2606
3.1	0.3410	0.1903	−3.00E−9	0.4583	0.4542	−1.70E−9	−0.2495	0.5367
3.2	0.1288	−0.0559	−4.4638	0.3301	0.0341	−4.80E−9	−7.0109	0.2791
4.0	0.6173	0.2802	−0.3554	0.6992	1.1359	6.00E−12	−9.10E−17	1.1494

Panel B: Constant Relative Risk Aversion (CRRA) Utility Function

		FR			BR1	BR2			BR3
Regime	Initial Wealth	$r = 10\%$	$r = 20\%$	$r = 30\%$	$r = 0\%$	$r = 10\%$	$r = 20\%$	$r = 30\%$	$r = 0\%$
1.1	$19,000	2.5061	2.4849	2.4598	2.5221	3.2015	3.1962	3.1891	3.2049
1.2	$19,272	1.4353	1.3327	1.0002	1.5233	1.1114	0.9703	0.8170	1.2345
2.1	$20,200	1.4407	1.3380	1.2251	1.5287	1.7622	1.7050	1.6443	1.8117
2.2	$21,222	0.7693	0.4945	0.1495	0.9849	0.4705	0.1004	−0.3814	0.7534
3.1	$21,139	0.5533	−0.0458	−1.1179	0.9292	0.6872	0.2519	−0.3146	0.9993
3.2	$19,685	0.2399	−0.9646	<-9	0.7752	0.0683	−1.6003	<-15	0.7025
4.0	$20,586	0.7817	0.3042	−0.3584	1.1125	1.1835	0.9957	0.8269	1.3540

Each regime is indexed by the value of the contestant's first draw. A .1 (.2) extension denotes an initial draw equal to the higher (lower) of the two intermediate dollar prizes. Fully rational (FR) contestants perform backward induction at each node of the tree, and discount annuity payments. Each contestant may use a different discount rate. We use discount rates of 10%, 20%, and 30%. Thus, FR, $r = 10\%$, refers to a fully rational contestant who discounts future cash flows using a 10% rate. Boundedly-rational-1 (BR1) contestants are the same as the FR contestants with the exception that they use a discount rate of 0 (i.e., they do not discount future payments). Though boundedly rational-2 (BR2) contestants discount future cash flows, they act myopically in that they ignore the option value of continuing to play the game. Boundedly-rational-3 (BR3) contestants ignore the option value of continuing to play the game, and they use a discount rate of 0. The CARA utility function is specified as follows: $U(W) = -e^{-aW}$, where W is the individual's initial wealth and a is the risk-aversion parameter. The CRRA utility function is specified as follows: $U(W) = W^{1-b}/(1 - b)$, where W is the individual's initial wealth and b is the risk-aversion parameter. Initial wealth refers to the median amount of winnings in phase 1 of the *Hoosier Millionaire.*

assumptions about the reference wealth level that individuals use to make decisions. We first use a restrictive definition of wealth, W_0, encompassing only the winnings accumulated in *Hoosier Millionaire.* This partial asset integration in decision-making is to some extent consistent with Kahneman and Tversky's (1979) prospect theory. As a test of robustness we will also use a broader wealth definition (W_1), which includes the median household income of the individual's census tract in 1990.

Table 2 shows the values for the CARA and CRRA (W_0) parameters that make contestants indifferent between gambling and keeping the sure prospect on every initial subgame in every regime of *Hoosier Millionaire*. That is, for any risk-aversion parameter larger than a given entry in this table, the contestant will prefer the sure prospect to the gamble.

As expected, as discounting increases, the value of the $1,000,000 annuity payments becomes small relative to that of the lump-sum payoffs. Thus, at some discount rate the expected value of a gamble becomes smaller than the sure prospect, and the contestant would have to be a risk lover to gamble (see the appropriate entries in table 2 when $r = 20\%$ and $r = 30\%$). Also, for a given discount rate, the risk-aversion coefficient that dissuades a contestant from gambling decreases with the amount of the sure prospect, regardless of the degree of contestant rationality. This follows from certainty equivalence.

IV. Data

We obtained the *Hoosier Millionaire* data from the Hoosier Lottery office in Indianapolis, and from press releases in the *South Bend Tribune*. With a few exceptions, our data set contains the winnings and census tract characteristics of all the participants in both phases of *Hoosier Millionaire* since its inception.

Table 3 presents a summary of the contestants' endogenous initial gambling decisions.[8] We also report mean phase I winnings and 1990 census tract median income figures for our sample. As seen in table 3, although 58% of the individuals in our sample take the initial gamble, this fraction varies across regimes. In fact, the rough comparative statics of decisions across regimes indicate that contestants respond correctly to changes in the award structure. For instance, in regime 1 the sizable consolation prize ($25,000) substantially reduces the downside of gambling. As a result, all of the contestants in this regime choose to gamble. This contrasts with regime 3, where the small consolation prize ($1,000) makes the downside of gambling

[8] We concentrate on the initial gambling decisions in view of the very limited number of individuals choosing to gamble more than once. In regimes 1–3 contestants face a compulsory (exogenous) initial gambling decision. Thus we consider only on the (endogenous) decisions after that compulsory stage. In contrast, all initial gambling decisions in regime 4 are endogenous.

TABLE 3.—DESCRIPTIVE STATISTICS

Regime	Take Gamble?	Sample Size	Phase 1 Winnings	Median Income	Per Capita Income
1.1	No	0	N.a.	N.a.	N.a.
	Yes	5	$19,000	$26,101	$11,323
	Total	5	$19,000	$26,101	$11,323
1.2	No	0	N.a.	N.a.	N.a.
	Yes	11	$19,727	$20,831	$11,149
	Total	11	$19,727	$20,831	$11,149
2.1	No	2	$16,500	Missing obs.	Missing obs.
	Yes	13	$20,769	$27,300	$11,991
	Total	15	$20,200	$27,850	$12,374
2.2	No	14	$21,143	$29,702	$13,436
	Yes	4	$21,500	$28,500	$12,937
	Total	18	$21,222	$29,419	$13,319
3.1	No	16	$21,281	$27,790	$13,087
	Yes	2	$20,000	Missing obs.	Missing obs.
	Total	18	$21,139	$27,647	$12,986
3.2	No	24	$19,688	$27,114	$11,872
	Yes	3	$19,667	Missing obs.	Missing obs.
	Total	27	$19,685	$27,770	$12,032
4.0	No	59	$20,829	$28,063	$12,636
	Yes	129	$20,474	$27,448	$12,655
	Total	188	$20,586	$27,645	$12,649
Total		282	$20,493	$27,525	$12,563
Indiana				$28,797	$13,149

Each regime is indexed by the value of the contestant's first draw. A .1 (.2) extension denotes an initial draw equal to the higher (lower) of the two intermediate dollar prizes. Phase 1 refers to the preliminary phase of *Hoosier Millionaire*, during which contestants randomly draw cash prizes. The contestant amassing the most cash in phase 1 moves on to phase 2, where she is confronted with the gambles analyzed in this paper. Income figures are from the 1990 Census. Median and per capita incomes are not available for all contestants, due to lack of demographic information. This affects seven contestants in regime 4, two in regime 2, and two in regime 1. "Missing obs." denotes a cell in which demographic information is missing for at least one contestant. N.a. = nonapplicable.

rather onerous, thus inducing 40 of 45 contestants to keep the sure prospect.

The fourth column of Table 3 shows phase 1 winnings for each contestant in our data set. As seen, there is not much variation in these winnings. We obtained the addresses of all phase 2 *Hoosier Millionaire* contestants, and found matching data from their 1990 census tracts. Table 3 also shows the average median family and per capita income for our sample. Although both of these income measures are below state averages, they are not significantly different from them.[9] However, there is no systematic difference between the incomes of contestants that took the gambles and contestants that chose the certain prospects.[10]

V. Estimation

A. Methodology

Previous studies such as those of Gertner (1993), Metrick (1995), and Hersch and McDougall (1997) estimated the coefficient of absolute risk aversion using a nonlinear probit approach. Unlike those studies, where individuals face gambles involving different stakes, each contestant within a regime of *Hoosier Millionaire* faces a gamble with identical stakes. Thus the probit technique is inappropriate, because a key source of variation—that between the sizes of the gambles—is absent.

Instead, we use a probabilistic approach and estimate the distribution of the risk-aversion parameter. We assume that contestants are endowed with risk-aversion parameters that are independent draws from a normal population distribution.[11] If a contestant's realization of the risk-aversion parameter is less than the value that yields indifference (equality of expected utilities from gambling and not gambling), she chooses the gamble. The probability that the contestant's risk-aversion parameter lies below the indifference value is given by the value of the cumulative normal distribution evaluated at the indifference value.

As we know, the normal distribution is determined by its mean and standard deviation. To estimate these parameters, we use the indifference values in table 2 and the binomial probabilities implied by the empirical frequencies in table 3. We infer the mean and standard deviation as follows: Each subgame in the history of *Hoosier Millionaire* is associated with a CARA or CRRA indifference parameter, which we denote ρ, and an observed frequency of taking the gamble, denoted p. We choose pairs of subgames, and solve for the (unique) values of the mean μ and standard deviation σ that satisfy the following system:

$$\int_{-\infty}^{\rho_1} (2\pi\sigma^2)^{-1/2} e^{-(\mu-x)^2/2\sigma^2}\, dx = p_1, \tag{3a}$$

$$\int_{-\infty}^{\rho_2} (2\pi\sigma^2)^{-1/2} e^{-(\mu-x)^2/2\sigma^2}\, dx = p_2. \tag{3b}$$

We then used Monte Carlo simulations to place confidence intervals around the estimated mean and standard deviation. For each Monte Carlo trial, we generated two data sets consisting of indicator random variables, and used the implied p's from these pseudo data to solve for μ and σ. The data-generating process for each set of indicator variables was a binomial distribution with parameter (probability of success on each binomial trial) equal to the observed p from the respective subgame. The number of observations in each set of pseudo data was set equal to the number of actual observations of the respective subgame. We repeated this experiment 1,000 times for each regime pair and behavioral

[9] Hersch and McDougall (1997) note that the median income of Illinois lottery players is nearly identical to the statewide figure. Although no figures are presented to back this claim, its accuracy is subject to the same problem regarding the coarseness of variables within census tracts.

[10] We also collected other census tract data for our contestant sample, like schooling, household size, and age. We do not show this information, due to its coarseness and insignificant interregime variation.

[11] Although we choose a normal distribution for our analysis, the results are qualitatively similar if we use a one-parameter symmetric distribution, such as the logistic distribution. We do not know ex ante if risk-aversion parameters are symmetrically distributed among individuals, but we are unaware of hard evidence showing otherwise.

TABLE 4.—ESTIMATES OF RISK-AVERSION COEFFICIENTS

Utility-Function Specification		Coefficient at Rationality Assumption FR $r = 10\%$	BR1 $r = 0\%$	BR2 $r = 10\%$	BR3 $r = 0\%$
CARA	Mean	4.8221	5.9715	8.3127	9.0882
	(90% c.i.)	(4.2107, 5.3983)	(5.5370, 6.4775)	(7.0160, 9.6262)	(8.2018, 10.3005)
	Std. dev.	0.1702	0.1479	0.2556	0.2271
	(90% c.i.)	(0.1428, 0.2017)	(0.1224, 0.1754)	(0.2159, 0.3029)	(0.2159, 0.3029)
CRRA	Mean	0.6319	1.0193	0.8752	1.1738
$W_0 = \$20,000$	(90% c.i.)	(0.5750, 0.6970)	(0.9746, 1.0585)	(0.7389, 1.0288)	(1.0986, 1.2589)
	Std. dev.	0.5667	0.4471	0.8130	0.6214
	(90% c.i.)	(0.4771, 0.6676)	(0.3751, 0.5274)	(0.6774, 0.9517)	(0.5232, 0.7268)
CRRA	Mean	0.8078	1.2430	1.0598	1.3911
$W_1 = \$48,000$	Std. dev.	0.6504	0.5061	0.8951	0.6755

Estimates of risk-aversion coefficients are obtained by using maximum likelihood and observations from regimes 4.0 and 3.2 to estimate the system of equations described in equations (3a)–(3b) of the text. Each regime is indexed by the value of the contestant's first draw. A .2 extension denotes an initial draw equal to the lower of the two intermediate dollar prizes. Fully rational (FR) contestants perform backward induction at each node of the tree, and discount annuity payments. Each contestant may use a different discount rate. Thus, FR, $r = 10\%$, refers to a fully rational contestant who discounts future cash flows using a 10% rate. Boundedly-rational-1 (BR1) contestants are the same as the FR contestants with the exception that they use a discount rate of 0 (that is, they do not discount future payments). Although boundedly-rational-2 (BR2) contestants discount future cash flows, they ignore the option value of continuing to play the game. Boundedly-rational-3 (BR3) contestants ignore the option value of continuing to play the game, and they use a discount rate of 0. The CARA utility function is $U(W) = -e^{-aW}$, where W is the individual's initial wealth and a is the risk-aversion parameter. The CRRA utility function is $U(W) = W^{1-b}/(1-b)$, where W is the individual's initial wealth and b is the risk aversion parameter. Two estimations are done for the CRRA utility function. The first uses an initial wealth (W_0) of \$20,000, and the second uses an initial wealth (W_1) of \$48,000. Standard deviation is abbreviated Std. dev., and confidence interval is abbreviated c.i.

assumption, ranked the estimated means and standard deviations, and identified 90% confidence intervals.

Although we performed this experiment using several pairs of subgames, we focus on the pairing of regimes 4 and 3.2.[12] Table 4 reports estimated means and variances of the CARA and CRRA coefficients for each behavioral assumption, along with the Monte Carlo-generated 90% confidence intervals.

B. Results

A feature of our results is their robustness across utility specifications. The parameter estimates for the CARA and CRRA (W_0) functions yield similar distributions and exhibit comparable patterns. The following discussion makes use of this similarity by grouping the results from both specifications whenever possible.

First, our results consistently support risk aversion. Estimated mean risk-aversion coefficients are always positive, and the confidence intervals around these means never include zero. Mean risk-aversion parameter estimates under CARA range from 4.8E−6 to 9.7E−6, and those under CRRA range from 0.64 to 1.43. Moreover, the minimum means implied by the Monte Carlo simulations are always positive. This evidence supports the hypothesis that on average, the individuals on our sample are risk-averse. However, the estimated standard deviations of the risk-aversion parameters indicate that some individuals may display risk-neutral or risk-loving preferences. This is particularly the case for CRRA utility, where a significant fraction of estimated risk-aversion parameters are nonpositive. A two-standard-deviation interval around the mean risk-aversion parameter generally includes only positive values for the CARA utility function but encompasses zero and negative values for the CRRA one.

Our second main result is that different behavioral assumptions affect the estimates of mean risk aversion. For

[12] Strictly speaking, the distribution parameters are overidentified, as there are several regime pairs that could be used to estimate them. However, the choice of regime pairs does not introduce major qualitative variations in the estimates. The similar results we obtained in the logistic case, which is not subject to the pairing problem, reinforce this point.

TABLE 5.—CERTAINTY EQUIVALENTS FOR VARIOUS GAMBLES IMPLIED BY MEAN ESTIMATES OF RISK-AVERSION COEFFICIENTS

Utility-Function Specification	Rationality Assumption	Certainty Equivalents for a 50-50 Gamble with Payoffs of 0 and X: $X = \$1,000$	$X = \$10,000$	$X = \$100,000$	$X = \$1,000,000$
CARA	FR ($r = 10\%$)	\$499.19	\$4,918.72	\$42,009.92	\$106,349.69
	BR1 ($r = 0\%$)	\$499.12	\$4,911.67	\$41,343.34	\$97,951.80
	BR2 ($r = 10\%$)	\$498.84	\$4,883.98	\$38,788.49	\$74,644.68
	BR3 ($r = 0\%$)	\$498.79	\$4,879.16	\$38,355.07	\$71,667.27
CRRA	FR ($r = 10\%$)	\$493.74	\$4,481.46	\$28,467.81	\$115,650.35
$W_0 = \$20,000$	BR1 ($r = 0\%$)	\$492.38	\$4,369.92	\$24,366.97	\$69,882.17
	BR2 ($r = 10\%$)	\$492.31	\$4,364.10	\$24,165.69	\$68,108.35
	BR3 ($r = 0\%$)	\$491.26	\$4,278.34	\$21,353.71	\$47,382.34

Estimates of risk-aversion coefficients are obtained by using maximum likelihood and observations from regimes 4.0 and 3.2 to estimate the system of equations described in equations (3a)–(3b) of the text. Each regime is indexed by the value of the contestant's first draw. A .2 extension denotes an initial draw equal to the lower of the two intermediate dollar prizes. Fully rational (FR) contestants perform backward induction at each node of the tree and discount annuity payments. Each contestant may use a different discount rate. FR ($r = 10\%$) refers to a fully rational contestant who discounts future cash flows using a 10% rate. Boundedly-rational-1 (BR1) contestants are the same as the FR contestants with the exception that they use a discount rate of 0 (that is, they do not discount future payments). Although boundedly-rational-2 (BR2) contestants discount future cash flows, they ignore the option value of continuing to play the game. Boundedly-rational-3 (BR3) contestants ignore the option value of continuing to play the game, and they use a discount rate of 0. The CARA utility function is $U(W) = -e^{-aW}$, where W is the individual's initial wealth and a is the risk-aversion parameter. The CRRA utility function is $U(W) = W^{1-b}/(1-b)$, where W is the individual's initial wealth and b is the risk-aversion parameter.

fixed discounting, confidence intervals for these means under full rationality (FR) and lack of backward induction (BR2 and BR3) are mutually exclusive. In addition, when comparing no discounting and 10% discounting, holding behavior fixed, confidence intervals are mutually exclusive in three of four cases. We discuss the direction and significance of these differences in the next section.

As a test of robustness of our CRRA results, we estimated the distribution parameters using a more inclusive definition of wealth (W_1). In this specification, in addition to phase I winnings, the initial wealth also included the average median income for the contestant's census tract in 1990. As we see in table 4, the higher initial wealth uniformly increases the means and standard deviations of the CRRA parameter distributions. However, most of these increases are very small (between 0.1 and 0.3) and, as we show in the next section, do not affect the basic interpretation of the results. The similarity between the two sets of CRRA estimates is due to the fact that that both wealth definitions are a small fraction of the stakes of the gambles in *Hoosier Millionaire.*[13]

VI. Discussion and Conclusions

The results from the previous section uniformly indicate that most individuals display some degree of risk aversion. To gain insight into the economic significance of these results, we first compare them with those obtained in related work. Our estimated means of the CARA parameter distributions are lower than the estimated CARA parameters of other game-show studies. Gertner (1993), using two alternative methods, estimates statistically significant lower bounds on this parameter of 0.000310 or 0.0000711. Metrick (1995) and Hersch and McDougall (1997) report estimates ranging from 0.0000265 to 0.000066, but these estimates are not statistically different from zero, leading to the conclusion of risk neutrality. In contrast, our largest estimated mean CARA parameter is 0.0000097, and the largest upper bound on a confidence interval is 0.000012, both of which are nearly an order of magnitude smaller than those reported elsewhere.

Our CRRA parameter estimates are also generally lower than those reported elsewhere. Friend and Blume (1975), using data from individual portfolio holdings, find estimates of this parameter ranging from 1 to 2, while Chou, Engle, and Kane (1992), in an asset-pricing context, estimate it to be around 3. Beetsma and Schotman (2001), using game data from *LINGO,* estimate it to be around 7. In our case the mean CRRA parameters range from 0.64 to 1.76, once again below most estimates from other studies.

To gain some intuition into the meaning of our results and how they compare with those of other studies, we calculate certainty equivalents implied by our mean estimates for a variety of gambles (see table 5). For instance, for a gamble offering a 50-50 chance of winning nothing and $1,000, the certainty equivalent ranges from $461.40 (Gertner, 1993) to $496.73 (Hersch and McDougall, 1997), with most estimates implying a certainty equivalent above $490. In our experiments, certainty equivalents implied by point estimates of the mean of the parameter distribution range from $491.26 to $499.40. Thus for gambles of this magnitude, not only are our results similar to those in other studies, but they imply behavior close to risk neutrality. Moreover, the tightness of the range of these certainty equivalents indicates that the differences among risk aversion parameters across behavioral assumptions may not have much economic significance when stakes like these are involved. In fact, as seen in table 5, near-risk-neutrality across all behaviors obtains even as stakes rise to several thousand dollars. This point, also emphasized on table 1 of Rabin and Thaler (2001), suggests that gambles of this size unavoidably lead to parameter estimates that imply near-risk-neutrality within the expected utility paradigm. Thus, given that most previous studies based their estimates on gambles with maximum stakes around $20,000, it is not surprising at all that the results point towards risk neutrality or mild risk aversion.[14]

However, we estimated our risk-aversion parameters from decisions involving unusually high stakes. In fact, stakes in *Hoosier Millionaire* are much higher (20 times or more in most cases) than those in any of the games analyzed in other studies. Thus, we must base our inferences on stakes of this magnitude. For instance, for a 50-50 gamble between winning nothing and $1 million, the certainty equivalents that our mean estimates imply range from $57,308 to $255,422, indicating substantial risk aversion. Moreover, there is wide variation of certainty equivalents, depending on rationality assumptions. More precisely, fully rational contestants display uniformly higher certainty equivalents than all boundedly rational contestants, and contestants who do not backward-induct and fail to discount their payoffs display the lowest certainty equivalents. These facts suggest that the willingness to take on large gambles is inversely related to the extent of rationality of the contestant. Because boundedly rational contestants fail to take account of for the option value of continuing to make decisions, their perceived expected utility of gambling is below that of a fully rational contestant. Table 5 also reports the CEs associated with two intermediate gambles, which show how risk aversion starts to surface more dramatically as the stakes grow larger.

[13] The income statistics are from the 1990 census (1989 figures), whereas the gambling figures are from 1992–1998. Although post-1989 contestant census tract figures are not available, the income variation within this period is not significant enough to meaningfully affect our CRRA estimates or its interpretation. For instance, median household income in Indiana was $31,776 in 1995, indicating only a modest nominal increase of 10.35% relative to 1989.

[14] The high risk-aversion parameters estimated by Beetsma and Schotman (2001) are an exception. Given the relatively small average stakes of their gambles (around $1500), it is possible that the subjective elements involved in their decisions are influencing their estimates.

What can we learn from these results? First, one should be very careful in drawing general conclusions about preferences from context-specific estimates. In our case, when taken in the context of previous studies, our estimates point towards very mild risk aversion. However, once we account for the actual context of our estimation, the results indicate substantial risk aversion. Thus, the recent claims in Rabin (2000a, 2000b) and Rabin and Thaler (2001) about the limited applicability of expected-utility theory when stakes are small should be taken very seriously. Second, not only does the size of the stakes affect risk-aversion inferences, but it is also very important in helping us distinguish across behaviors in decision-making problems. As we showed, estimates based on small stakes may yield decision rules that are economically indistinguishable for fully rational and boundedly rational decision-makers. Only at high stakes are these behavioral differences clearly observable.

Finally, a common criticism of field-study data pertains to the selection of participating subjects. It is possible that individuals participating in these games are in some sense different from the rest of the population. The evidence presented here and also in Hersch and McDougall (1997) suggests that this is not the case with regard to observable characteristics. However, our contestant sample is more likely to be selected from individuals who are heavy lottery ticket buyers. Thus our results can be interpreted as providing a quasi lower bound on the mean risk-aversion parameter for the population at large.

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THE SMALL-SAMPLE BIAS OF THE GINI COEFFICIENT: RESULTS AND IMPLICATIONS FOR EMPIRICAL RESEARCH

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Abstract—The Gini coefficient is a downward-biased measure of inequality in small populations when income is generated by one of three common distributions. The paper discusses the sources of bias and argues that this property is far more general. This has implications for (i) the comparison of inequality among subsamples, some of which may be small, and (ii) the use of the Gini in measuring firm size inequality in markets with a small number of firms. The small-sample bias has often led to misperceptions about trends in industry concentration. A small-sample adjustment results in a reduced bias, which can no longer be signed. This remaining bias rises with the dispersion and falls with increasing skewness of the distribution. Finally, an empirical example illustrates the importance of using the adjusted Gini. In this example it is shown that, controlling for market characteristics, larger shipping cartels include a set of firms that is stochastically identical (in terms of relative size) to those of smaller shipping cartels.

Received for publication January 28, 2000. Revision accepted for publication January 11, 2002.

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I would like to thank Anil Bera, Dan Bernhardt, Hadi Esfahani, Roger Koenker, Richard Sicotte, Eleftherios Zacharias, and an anonymous referee for useful discussion and comments. Partial financial support by the Illinois CIBER and the National Science Foundation (ECS-0000577) is gratefully acknowledged. Responsibility for any errors rests with me.

I. Introduction

THIS paper shows that the Gini coefficient statistic exhibits a significant small-sample bias. The Gini coefficient of a large population estimated from a small sample will be substantially smaller than the Gini of the entire population. Similarly, the Gini of a small population will be smaller than the Gini of a larger population generated by the

The Review of Economics and Statistics, February 2003, 85(1): 226–234