A Measure Of Risk Tolerance Based On Economic Theory

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Self-reported risk tolerance is a measurement of an individual's willingness to accept risk, making it a valuable tool for financial planners and researchers alike. Prior subjective risk tolerance measures have lacked a rigorous connection to economic theory. This study presents an improved measurement of subjective risk tolerance based on economic theory and discusses its link to relative risk aversion. Results from a web-based survey are presented and compared with results from previous studies using other risk tolerance measurements. The new measure allows for a wider possible range of risk tolerance to be obtained, with important implications for short-term investing.
Key words: *Risk tolerance, Risk aversion, Economic model*

Malkiel (1996, p. 401) suggested that the risk an investor should be willing to take or tolerate is related to the household situation, lifecycle stage, and subjective factors. Risk tolerance is commonly used by financial planners, and is discussed in financial planning textbooks. For instance, Mittra (1995, p. 396) discussed the idea that risk tolerance measurement is usually not precise. Most tests use a subjective measure of both emotional and financial ability of an investor to withstand losses. Mittra mentioned different factors related to risk tolerance including net worth, income, knowledge, sophistication, and proximity to retirement. Mittra suggested tests should determine emotional responses to varying situations about money and decisions one might make in a given financial circumstance.

The level of risk tolerance is a crucial part of individual choices about wealth accumulation, retirement, human capital investment, portfolio allocation, and insurance, as well as to policy decisions that are dependent on this behavior. For instance, Bajtelsmit and Bernasek (1996) discussed the differences between men and women in investing and risk tolerance. The increasing reliance on individual investment choices for retirement funds makes it clear that some groups in society may be at risk for inadequate retirement income if they are very averse to risk. However, risk tolerance measures used by financial planners are not based on rigorous economic concepts. The purpose of this paper is to present a measure of risk tolerance based on economic theory, and to describe some preliminary patterns of risk tolerance based on the measure. The results suggest that there is a wide variation of risk tolerance in people, but no systematic patterns related to gender or age have been found.

Literature Review

There are at least four methods of measuring risk tolerance: asking about investment choices, asking a combination of investment and subjective questions, assessing actual behavior, and asking hypothetical questions with carefully specified scenarios.

Investment Choice Measures

A good example of the first method is the Federal Reserve Board's Surveys of Consumer Finances (SCF). The SCF have since 1983 asked a risk tolerance question related to how much risk a respondent is willing to take for investments. Researchers using the SCF risk tolerance data found that only a minority of respondents are willing to take above average risks to make an above average return on investments. Sung and Hanna (1996) analyzed a subset of the 1992 SCF households, with employed respondents aged 16-70. Only 4% of the sample were willing to take substantial risks on investments in order to make a substantial return, and 40% were not willing to take any financial risks. Risk tolerance increased with education and income, and female headed households had lower risk tolerance than otherwise similar married couple and male headed households. Households meeting three

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month and six month thresholds of precautionary savings had higher risk tolerance than households not meeting these guidelines. Whites were more risk tolerant than otherwise similar households with a respondent of another race. Age was not significantly correlated with risk tolerance, but controlling for other factors, the number of years until retirement was related to risk tolerance.

Mixed Measures

The second type of measure involves asking a combination of investment and subjective questions. Mittra (1995, pp. 397-399), Grable and Lytton (1999; also p. 51 of this issue) and various financial companies on their web sites have examples of this type of measure of risk tolerance. For instance, Mittra presents two questionnaires, but both relate to investor choices regarding portfolio management actions. In addition, there are difficulties in quantifying a temperamental tolerance for risk (Hube, 1998). Hube noted that a drawback to giving these tests was the tendency for some investors to not be honest in order to avoid looking "wimpy." Hube also suggested that consultants should discuss their clients' ability to take any losses despite their risk tolerances.

One major drawback of these various financial planning measures of risk tolerance, as well as the SCF question related to risk tolerance is that they are not rigorously linked to the concept of risk tolerance in economic theory. The SCF question as well as measures similar to Mittra's may reflect a combination of the investor's current situation and/or the investor's limited information.

Assessing Actual Behavior Based on Economic Models

Risk tolerance is the reverse of the economic concept of risk aversion -- as risk aversion increases, risk tolerance decreases. The concept of risk aversion was independently developed by Pratt (1964) and Arrow (1965, as cited in Pålsson 1996). It is derived from household preferences and measures in broad terms the unwillingness to incur risk (Pålsson 1996).

Standard ways of defining risk aversion include the coefficient of absolute risk aversion and the coefficient of relative risk aversion. Following Arrow's exposition in 1963 lectures (1971, p. 94) and Pratt (1964), the coefficient of absolute risk aversion (B) is defined as shown in Equation 1 and the coefficient of relative risk aversion (A) is defined as shown in Equation 2.

$$B = -U''(C) / U'(C) \quad (1)$$

$$A = -U''(C)C / U'(C) \quad (2)$$

U is the utility function with the argument wealth, which is denoted as *C*. Merton (1969, p.256) suggested that the assumption that relative risk aversion did not change with wealth was more plausible than the assumption that absolute risk aversion did not change with wealth.

However, despite the analytic importance of this preference parameter, empirical studies have not fully resolved issues involving even their mean values (Barsky, Juster, Kimball & Shapiro, 1997) . There have been a number of empirical attempts to estimate the level of risk aversion based on household behavior. Several types of data have been utilized for such estimation, including consumption data, both micro and macro, historical stock market return data, and households' assets allocation information. With such estimations, the utility function is usually assumed to be the constant relative risk aversion utility function, and is specified as shown in Equations 3 and 4:

$$U = \frac{C^{1-A}}{1-A} \quad \text{when A} \neq 1 \quad (3)$$

$$U=\ln(C) \text{ when A=1} \quad (4)$$

Empirical estimates of *A* vary substantially, depending on the data, assumptions, and estimation methods. Some estimates using consumption data in the U.S. and in other western developed countries have been from less than 1 (Hanson & Singleton, 1981; Hurd, 1989; Shapiro, 1984) to 15 (Hall, 1988), but most estimates fall in the range of 1 to 6 (Attanasio & Weber, 1989; Mankiw, 1981; Skinner, 1985; Zeldes, 1989). Hanna, Fan and Chang (1995) summarize some of the empirical literature on this topic, though most of the literature is related to consumption smoothing in a lifecycle context rather than to decision-making under uncertainty.

Pålsson (1996) used Swedish cross-sectional data on portfolio allocation and estimated A to be between 2 to 4, when excluding housing as a type of financial asset. When the housing asset was included as a type of financial asset, then the estimated A was much higher at 10 to 14.

On the other hand, using equity premium data (the equity premium is the difference between the return on stocks and the return on risk-free assets such as Treasury bills), studies have found that a coefficient of relative risk aversion needs to be as high as 30 to 40 in order to explain the historical patterns of equity premium in the U.S. (Mehra & Prescott, 1985; Siegel, 1992a; 1992b). The fact that the required level of relative risk aversion to explain the equity premium is too high, both in its theoretical implication and in comparison to empirical estimates using consumption data, is called the equity premium puzzle (Siegel & Thaler, 1997).

It is possible that actual household behavior does not match economic models because most households have very low levels of liquid assets, and therefore cannot hold high levels of risky assets. Wang and Hanna's (1997) finding that all other things equal, the risky asset proportion of total wealth increased with age suggests that there may be problems in inferring risk tolerance from portfolio holdings. One way to address this problem is to use hypothetical scenarios.

Measures Using Hypothetical Scenarios Constructed Based on Economic Models

Barsky et al. (1997) presented an experimental measure based on presenting a set of hypothetical questions to a large national sample of adults aged 51 to 61. Their measurement linked the theoretical concept of relative risk aversion with the survey questions. Their questions are similar to this initial one:

> Suppose that you are the only income earner in the family, and you have a good job guaranteed to give you your current (family) income for life. You are given the opportunity to take a new and equally good job, with a 50-50 chance it will double your aftertax income and a 50-50 chance that it will cut your income by (1-λ)% (for example, a third). Would you take the new job?

By asking what percentage cut the respondent is willing to take, Barsky et al. (1997)'s measure essentially is asking under what value of λ is the respondent willing to take the risk. If the respondent chooses to take the risk, then based on expected utility theory, Equation 5 must hold.

$$.5\ U(2C) + .5\ U(\lambda C) \geq U(C) \qquad (5)$$

Assuming that the utility function is constant relative risk aversion in the relevant region, then Equation 6 below shows the relationship between the Arrow-Pratt measure of relative risk aversion A and λ:

$$\lambda = (2 - 2^{(1-A)})^{[1/(1-A)]} \qquad (6)$$

Equation 6 holds if $A \neq 1$, and $\lambda=0.5$ when $A=1$. Therefore, by asking questions with different levels of λ, the Arrow-Pratt coefficient of relative risk aversion A can be directly calculated.. For instance, if one is indifferent between the new job and the 50-50 change of doubling income or a one-third cut, then $1-\lambda = 0.3333$. Therefore, relative risk aversion must equal 2.0.

Table 1.
Hypothetical Choices and Relative Risk Aversion

λ	1-λ (% cut)	**A** (relative risk aversion)	Lower income	Expected value of risky job (per year)
0.00%	100.00%	0.00	$0	$50,000
50.00%	50.00%	1.00	$25,000	$62,500
66.67%	33.33%	2.00	$33,333	$66,667
75.59%	24.41%	3.00	$37,796	$68,898
80.00%	20.00%	3.76	$40,000	$70,000
84.01%	15.99%	4.76	$42,006	$71,003
86.80%	13.20%	5.76	$43,398	$71,699
88.81%	11.19%	6.76	$44,405	$72,203
90.00%	10.00%	7.53	$45,000	$72,500
90.62%	9.38%	8.00	$45,312	$72,656
92.00%	8.00%	9.29	$46,000	$73,000
93.49%	6.51%	11.29	$46,746	$73,373
94.52%	5.48%	13.29	$47,259	$73,630
95.00%	5.00%	14.51	$47,250	$73,750

Based on modified version of Barsky et al. (1997) hypothetical choices (see Appendix of this article):
Assume you could choose a certain aftertax income of $50,000 per year, or a job with a 50% chance of an aftertax income of $100,000 per year and a 50% chance of a lower aftertax income. What is the lowest income you would accept in order to have a 50% chance of $100,000 income?

Table 1 shows the relationship between the largest cut a respondent is willing to risk in order to have a 50% chance of doubling income, and relative risk aversion. Note that a risk neutral person (relative risk aversion = 0) would be willing to accept a 50% chance of zero income, even though the implicit assumption is that zero income would mean death, because there would be no other income. (The implicit assumption for the

hypothetical choices is that no other source of income would ever be available, though it is not clear that respondents to the Barsky et al. [1997] questions understood that.) Therefore, it is plausible that all rational consumers are risk averse to some degree.

Table 1 also shows the expected value of the risky job, assuming a 50% chance of $100,000 per year and a 50% chance of a lower income. If a consumer were not willing to accept a chance of even a slight reduction of income, relative risk aversion would be infinite. A consumer willing to accept at most a 50% chance of a 50% reduction of income in order to have a 50% chance of doubling income would have a relative risk aversion of no more than 1.0. A consumer willing to accept at most a 33.3% chance of a 50% reduction of income in order to have a 50% chance of doubling income would have a relative risk aversion of no more than 2.0. A consumer willing to accept at most a 50% chance of a 5% reduction of income in order to have a 50% chance of doubling income would have a relative risk aversion of no more than 14.5. A consumer *not* willing to accept a 50% chance of a 5% reduction of income in order to have a 50% chance of doubling income would have a relative risk aversion of more than 14.5.

Using a sample of 11,707 respondents, Barkey et al. (1997) found that 64.6% had a relative risk aversion level *(A)* between 3.76 and infinity, 11.6% had a value between 2 and 3.76, 10.9% had a value between 1 and 2, and 12.8% had a value between 0 and 1. Barsky et al (1997)'s measure is theoretically sound, but has at least three potential defects. The first defect is related to taxes. Their hypothetical questions are ambiguous with regards to gross income versus aftertax income. This could create a substantial bias both at the lower end of the income scale, where respondents might perceive a high effective marginal tax rate in terms of loss of benefits, and at the upper end of the income scale, where the combined marginal tax rate might approach 50%. The second defect is related to Barsky et al.'s failure to provide distinctions between levels of relative risk aversion above 3.8. The Barsky measure estimates four levels of risk aversion, but the most risk averse level is equivalent to a relative risk aversion level of 3.8 or higher, even though it might be useful to know different levels of risk aversion above that level. The third defect is based on ambiguity about what type of alternatives the respondent would have if he or she chose a 50-50 chance and the worse alternative resulted. For instance, if you chose a gamble and your income were cut by a third, would your income be forever cut by a third? It seems plausible that this alternative is not imagined by many respondents, especially by younger respondents, but in order for the Barsky et al. measure to reflect relative risk aversion, it is essential that respondents consider income drops to be permanent.

Purpose

The purpose of this paper is to test an improved version of the Barsky et al. risk aversion measure, and to relate it to the Barsky measure and to the SCF measure. The results have implications for issues such as explanation of the equity premium puzzle and appropriate risk tolerance measures for financial planners. For instance, many rigorous analyses of optimal portfolio allocations are either implicitly or explicitly based on risk aversion (e.g., Hanna & Chen, 1997).

Methods

The sets of questions estimating risk tolerance are shown in the Appendix. In addition to the SCF risk tolerance question, a modified version of the Barsky et al. (1997) questions were posed, and are referred to below as the Job Risk Tolerance measure. The Job measure extended the range of relative risk aversion that could be measured from the Barsky et al. level of greater than 3.8 to several levels, up to 14.5 or greater, assuming respondents had a constant relative risk aversion utility function. Modified questions (the Retirement measure) were also posed with the alternatives being described as hypothetical retirement income choices. The purpose of this change was to more rigorously suggest the idea that once the choice was made, the respondent would have to live with the outcomes forever. Unless a respondent implicitly accepts this idea in the hypothetical choices, it is not valid to infer relative risk aversion from the answers.

These questions, which are presented in the Appendix, were posted on the web. Students in three personal finance classes at Ohio State University were given extra credit for participating in the risk survey, and the survey was publicized in various ways, including email to members of several professional organizations. There were 390 valid responses. The age range of the respondents was from 19 to 57, with a mean age of 25. Table 2 shows the distribution of ages of respondents. Over 25% of the respondents were over age 24, and 28% were age 21 or under. About 58.6% of the respondents were male.

Table 2.
Distribution of Ages of Respondents to Web Survey on Risk Tolerance

Category	Number	Percent
19-21	104	27.59%
22-24	179	47.48%
25-34	61	16.18%
35-57	33	8.75%
Total	377	100.00%

Note: Not all respondents entering answers to the risk tolerance questions gave their ages.

Results and Discussion

Table 3 shows the combined responses to the modification of the Barsky et al. income loss questions, and compares the frequencies to the Barsky et al. national sample, and the responses to the SCF risk tolerance question and the 1998 SCF results.

Comparison of Our Sample and the SCF Sample

The respondents in our survey were much less likely than the SCF respondents to state that they would take no financial risks with their investments (11% in our survey and 39% in the SCF). A much higher percentage of our respondents (37%) were willing to take above-average financial risks expecting to earn above-average returns than the SCF sample (18%). Overall, using the SCF risk tolerance measure, our sample was less risk averse than the SCF sample.

Comparison of Our Results with Barsky Results

In our Web survey, two measures were used, the Retirement risk tolerance measure and the Job risk tolerance measure. The level of risk tolerance measure by the Retirement risk tolerance measure was significantly lower than that measured by the Job risk tolerance measure. Compared to our sample using the Retirement measure, the Health and Retirement Study (HRS) results reported by Barsky, et al. (1997) were more likely to be extremely risk tolerant (12.8% for HRS vs. 1.0% for our sample), or had a very high level of risk tolerance (10.9% for HRS vs. 5.1% for our sample). Overall, when the Retirement measure was used, our sample was found to be less risk tolerant than the HRS sample. However, the Job measure shows that our respondents were more likely to have either very high or moderately high levels of risk tolerance, compared to the HRS respondents. This difference implies the importance of income flow specifications in a risk-tolerance questionnaire.

Table 3.
Comparison of Web Survey Responses to Barsky et al. (1997) and to Survey of Consumer Finances Risk Tolerance Responses.

Survey of Consumer Finance Risk Tolerance Question:	N	%	%
Which of the statements on this page comes closest to the amount of financial risk that you are willing to take when you save or make investments?			
	Web Survey (n=390)		1998 SCF*
Substantial financial risks expecting to earn substantial returns.	28	7.2%	4.9%
Above-average financial risks expecting to earn above-average returns.	146	37.4%	17.9%
Average financial risks expecting to earn average returns.	174	44.6%	38.5%
No financial risks.	42	10.8%	38.8%
Revised Version of Barsky et al. Risk Tolerance Question			
	Web Survey (n=390)		
	Retire	Job	Barsky†
Extremely High, accept 50% cut (A‡< 1.0)	1.0%	2.8%	12.8%
Very High, reject 50% cut (1.0 ≤ A < 2.0)	5.1%	16.4%	10.9%
Moderately High, reject 33% cut (2.0 ≤ A< 3.8)	22.1%	45.4%	11.6%
Moderate, accept 10% cut (3.8 ≤ A< 7.5)	43.6%	24.4%	64.6%
Low, accept 8% cut (7.5 ≤A< 9.3)	9.7%	2.6%	
Very Low, accept 5% cut (9.3 ≤ A 14.5)	7.4%	2.1%	
Extremely Low, reject 5% cut (A>14.5)	11.0%	6.4%	
Mean Relative Risk Aversion **	7.76	5.61	

*Weighted tabulation of respondents, 1998 Survey of Consumer Finances (Rha, Montalto & Hanna (2001).
† Barsky et al. (1997) results, national sample of 11,707 respondents to the Health and Retirement Study, individuals aged 51 through 61 in 1992.
‡ A is relative risk aversion level consistent with responses to hypothetical income loss questions.
** Weighted average based on midpoints of each range, except value of 0.9 used for "Extremely High" category, and 16.0 used for "Very Low category.
Chi square statistic for difference between distribution of Retirement and Job risk tolerance measures significant at 0.001 level.

Table 4.
Comparison of Web Survey Responses by Gender

Retirement Version of Risk Tolerance Question	male		female	
	N	%	N	%
Extremely High, accept 50% cut (A< 1.0)	0	0.0%	2	1.4%
Very High, reject 50% cut (1.0 ≤ A < 2.0)	12	5.8%	6	4.1%
Moderately High, reject 33% cut (2.0 ≤ A< 3.8)	48	23.2%	30	20.6%
Moderate, accept 10% cut (3.8 ≤ A< 7.5)	94	45.4%	60	41.1%
Low, accept 8% cut (7.5 ≤A< 9.3)	14	6.8%	21	14.4%
Very Low, accept 5% cut (9.3 ≤ A 14.5)	18	8.7%	10	6.9%
Extremely Low, reject 5% cut (A>14.5)	21	10.1%	17	11.6%
Entire sample	207	100.0%	146	100.0%
Mean Relative Risk Aversion*	6.55		6.88	

Web Survey (n=353) Note that not all respondents indicated their gender.
*Weighted average based on midpoints of each range, except value of 0.9 used for "Extremely High" category, and 16.0 used for "Very Low category.
Chi square statistic not significant.

Based on the Retirement risk tolerance measure, over 18% of the respondents had relative risk aversion levels over 9.3, and therefore portfolios dominated by stocks might not be appropriate for goals with short horizons (Hanna & Chen, 1997).

Factors Associated with Measured Risk Tolerance

When comparing the answers to the SCF risk tolerance measure and to our risk tolerance measures, no statistically significant correlations were found, for either the Job risk tolerance measure or the Retirement measure. There were no significant Pearson correlations between age and any of the three risk tolerance measures. There was also no significant correlations between any of the risk tolerance measures and gender.

Conclusions

The hypothetical Retirement risk tolerance measure may provide a useful way to determine a client's inherent risk tolerance level. It is possible that the client's risk tolerance level measured this way, combined with the investment horizon, could provide the basis for reasonable portfolio recommendations. An important advantage of the Retirement risk tolerance measure presented in this paper is that it provides as pure a measure of inherent risk tolerance as possible, stripping away situational constraints, as well as to some extent removing client responses based on lack of information.

It is obvious that our sample does not provide a nationally representative sample, so that this paper represents an exploratory study. However, Barsky et al. (1997) started with exploratory student samples and then placed their questions on a large nationally representative survey. Perhaps this article could lead to an improved set of questions on a national survey. The fact that our web sample was much more risk tolerant in terms of the SCF risk tolerance than the levels in the 1998 national SCF sample, yet had a mean level of relative risk aversion above the level above the highest category measured by

Barsky et al. (1997) suggests that future efforts to measure risk tolerance should allow for very low levels of risk tolerance (high levels of relative risk aversion.)

Our finding that many respondents seemed to be very risk averse does not mean that stock portfolios should be avoided for long term goals, since as Hanna and Chen (1997) showed, even very risk averse consumers should have 100% stock portfolios for long term goals. However, as the retired population grows substantially in the next 10 years, measurement of risk tolerance in a way better linked to economic theory will become even more important for those giving advice to consumers about investing.

Appendix
Measures of Subjective Risk Tolerance

Job Measure (Similar to Barsky et al. question, except stating income alternatives as aftertax, adding "equally good job" and including more levels of high risk aversion (low risk tolerance.)

Income Loss Questions Estimating Risk Tolerance

1. Suppose that you are the only income earner in the family, and you have a good job guaranteed to give you your current (family) income for life. You are given the opportunity to take a new and equally good job, with a 50-50 chance it will double your aftertax income and a 50-50 chance that it will cut your aftertax income BY 20%. Would you take the new job?
   If your answer to #1 is NO, go to question #2.

   If your answer to #1 is YES, go to question #5.

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2. Suppose the chances were that there was a 50-50 chance it will double your aftertax income and a 50-50 chance that it will cut your aftertax income BY 10%. Would you take the new job?
   If your answer to #2 is NO, go to question # 3.

   If your answer to #2 is YES, your risk tolerance is MODERATE.

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3. Suppose the chances were that there was a 50-50 chance it will double your aftertax income and a 50-50 chance that it will cut your aftertax income BY 8%. Would you take the new job?
   If your answer to #3 is NO, go to question #4.

   If your answer to #3 is YES, your risk tolerance is LOW.

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4. Suppose the chances were that there was a 50-50 chance it will double your aftertax income and a 50-50 chance that it will cut your aftertax income BY 5%. Would you take the new job?
   If your answer to #4 is NO, your risk tolerance is EXTREMELY LOW.

   If your answer to #4 is YES, your risk tolerance is VERY LOW.

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5. Suppose the chances were that there was a 50-50 chance it will double your aftertax income and a 50-50 chance that it will cut your aftertax income BY A THIRD. Would you take the new job?
   If your answer to #5 is NO, your risk tolerance is MODERATELY HIGH.

   If your answer to #5 is YES, go to question 6.

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6. Suppose the chances were that there was a 50-50 chance it will double your aftertax income and a 50-50 chance that it will cut your aftertax income IN HALF. Would you take the new job?
   If your answer to #6 is NO, your risk tolerance is VERY HIGH.

If your answer to #6 is YES, your risk tolerance is EXTREMELY HIGH.

Retirement Measure of Risk Tolerance (Similar to Job Measure question above, but stated in terms of hypothetical retirement income alternatives.

Suppose that you are about to retire, and have two choices for a pension.

1. You would have a pension equal to your takehome family income now.
2. There would be a 50-50 chance the pension would double your takehome income and a 50-50 chance that it be 20% less than your takehome.

You would have no other source of income, and no chance of employment or help from family, friends, or agencies. Which would you prefer, Choice 1 or Choice 2?

The remaining questions are similar to the series of questions for the Job measure.

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