Why Aristotle didn't get his flu shot: Experimental measures of Prudence and Prevention*

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Abstract

Prudence preferences have been shown to influence precautionary savings, asset allocation, and optimal prevention levels. In this paper, we will collect data from an experimental setting to measure prudence non-parametrically over both gains and losses. We find that 53.1% of individuals are prudent and 15.0% are imprudent. These preferences are constant regardless of the individual's level of risk aversion. Contrary to previous work in the literature, our results demonstrate that estimating prudence using parametric assumptions on the utility function often incorrectly categorizes risk lovers as imprudent. We also provide suggestive evidence that individuals classified as prudent are more likely to choose lower levels of prevention.

Keywords: Risk attitudes, prudence, prevention, economic experiment
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1 Introduction

Throughout history, prudence has been seen as one of mankind's ultimate virtues. Aristotle defined prudence or *phronesis* ($\phi\rho\acute{o}\eta\sigma\iota\varsigma$) as man's ability to think well about the nature of the world. He also stated that "the full performance of man's functions depends upon a combination of prudence and moral virtue; virtue ensures the correctness of the end at which we aim, and prudence that of the means towards it." Thomas Aquinas believed prudence was one of man's four principal virtues–along with temperance, justice, and fortitude.

In the field of economics, prudence is defined less poetically but perhaps more concisely. Seminal work by Kimball (1990) claims that an individual is prudent only if the third derivative of an agent's utility function is positive. Given lotteries with the same expected value and variance, prudent individuals prefer lotteries with more upside risk (i.e., right-skewed) to those with more downside risk (i.e., left-skewed). Prudence has been shown to be an important factor in areas such as intertemporal savings decisions (Kimball, 1990), asset allocation (Gomes and Michaelides, 2005) to preventive care decisions (Courage and Rey, 2006).

In this paper, we use a new non-parametric methodology to measure prudence preferences. Dat was collected from 113 individuals using an online survey. We find that 53.1% of individuals are prudent and 15.0% are imprudent. Kahneman and Tversky 1979 suggest that risk preferences may vary significantly depending on whether a outcomes are perceived as gains or losses from a status quo. To test this point, we repeat our tests over both over gains and losses. We find that 56.6% of individuals are prudent over gains, but only 45.1% are prudent over losses. On the other hand, 17.7% of individuals are imprudent over gains, while 19.5% of individuals are imprudent over losses. Moreover, we found that both risk averse and risk loving individuals evince a strong preferences for prudence. This gives rise to the complementarity of both concepts (Eeckhoudt and Schlesinger 2006).

Our research also questions the usefulness of employing parametric utility function assumptions to capture prudence preferences. We fit constant relative risk aversion (CRRA) utility function parameters to individual responses regarding certainty equivalents. Parameter estimates from the CRRA utility function predict that 53 of 133 individuals should be imprudent. Of these 53 individuals, however, only 17.0% were imprudent and 56.6% were prudent. This suggests that functional form assumptions may be a poor method to estimate prudence preferences.

In order to verify that our experimental design truly does test for prudence, we present risky alternatives in two different ways. One method asks individuals to choose between two lotteries which are mean-variance preserving transformations of one another. Probabilities and outcomes are presented as "ballot boxes." In a second "coin flip" specification, we present individuals with a single 50:50 lottery. We then ask individuals to attach a zero mean risk to either the 'good' or the 'bad' outcome of the lottery. Preferences for prudence are consistent across both specifications.

Prudent preferences also can affect optimal levels of prevention. Because prudent individuals prefer to avoid very 'bad outcomes,' electing higher levels of prevention involves a chance of a worse outcome. For instance, if you decide to get a flu shot, this reduces the probability that you get the flu. However, you still have some probability—albeit smaller—of getting sick. Getting the flu *and* paying for a flu shot is worse than just getting the flu. Hence, a prudent individual such as Aristotle would prefer lower levels of prevention and may be less likely to receive a flu shot.

In this paper, we use our data to test whether or not prudent individuals select lower levels of prevention than imprudent individuals. Prevention is tested in a neutral framing. Selecting a higher level of prevention involves a larger up-front payment, but it also reduces the probability of a larger loss. In general, we find suggestive evidence that higher levels of prudence are associated with lower levels of prevention.

The paper proceeds as follows. Section 2 will give a brief literature review. Section 3 will define prudence in more detail and outline the expected utility theory of why prudence will affect risk aversion. In Section 4 we explain our experimental methodology and section 5 we give our preliminary results. We conclude in section 6.

2 Related literature

2.1 Prudence

Before we discuss our methodology, we must first rigorously define what is meant by the terms "prudence" and "prevention." Eeckhoudt and Schlesinger (2006) provided a definition of prudence outside of expected utility theory. If $\tilde{\epsilon}$ is a non-degenerate, zero mean random variable and k is a positive constant, than a prudent person will always have the following preferences: $[-k, \frac{1}{2}; \tilde{\epsilon}, \frac{1}{2}] \succeq [0, \frac{1}{2}; \tilde{\epsilon} - k, \frac{1}{2}]$. Further, if we define a risk premium as $w_r(x) = Eu(x + \tilde{\epsilon}) - u(x)$, then we can similarly define a prudence premium (i.e.: the change in the risk premium as wealth changes) by $w_p(x) = w'_r(x) = Eu'(x+\tilde{\epsilon}) - u'(x)$. Using Jensen's inequality, the prudence premium is positive if and only if $u''' > 0$ (i.e.: u' is convex).

Kimball (1990) also demonstrated that an individual is prudent when the third derivative of their utility function is positive (i.e.: $u''' > 0$) and imprudent when this term is negative (i.e.: $u''' < 0$). The Kimball paper is of particular note since the research demonstrated that prudence will lead to "precautionary savings" in a two period model where income is uncertain in the second period.

Menezes et al. (1980) defined prudence as "downside risk aversion." Critical to our empirical work, this paper proved that a prudent person prefers lottery A to lottery B if lottery A was a particular mean-variance preserving transformation (MVPT) of lottery B. This MVPT must include a mean preserving contraction at the left tail of the distribution and a mean preserving spread at the right tail of the distribution. By moving from lottery A to lottery B, we switch from a lottery with more downside risk (lottery A) to one with more upside risk (lottery B). In other words, comparing two random variables whose distributions have the same first two moments, a prudent person prefers the lottery whose the distribution is right skewed (positive skewness) compared to the lottery that is left skewed (negative skewness).

Several empirical studies attempt to test for prudence as defined within the EUT-framework. In his seminal article Mao (1970) elicited preferences about uncertain investment opportunities varying in their third moment. Executives of leading US-companies participated in his (non-incentivized) survey study. He found that 4 out of 8 queried executives exhibited preferences for the lottery with the positive skew. More recently Unser (2000) analyzes individual's risk perception by applying the concept of lower partial moments. Within a complex financial decision context students were asked in a (non-incentivized) classroom experiment to state their preferences over several different risky assets. Using data from an Italian household survey, Eisenhauer and Ventura (2003) measure absolute and relative prudence for a broad cross-section of Italian household concerning financial investments. They found evidence for decreasing absolute and increasing relative prudence.

A first attempt to test for prudence using the means of experimental economics was put forward by Gomez (2003). She determines prudence parameters by eliciting individuals' preferences over lottery pairs. The work allows individuals to attach a mean preserving increase in risk to either the best lottery outcomes (the prudent choice) or the worst outcomes (the imprudent choice). She found that more than 60% of the individuals to exhibit a prudent behavior. An experimental study by Deck and Schlesinger (2008) tests for higher order risks, i.e. prudence and temperance, outside the expected utility theory framework. Participating subjects are asked to make eight decisions between lottery pairs of the form introduced by Eeckhoudt and Schlesinger (2006). The authors find some evidence for prudence but no evidence for temperance.

2.2 Prevention

Prevention is defined in a very strict mathematical sense. Let the variable e represent the amount of preventive effort and let $p(e)$ represent the probability of a loss. Within the expected utility framework, we can calculate the individual's decision function as follows:

$$e^* \equiv max_e \quad p(e)u(w - L - e) + [1 - p(e)]u(w - e). \tag{1}$$

The loss L could be a financial loss, a decrease in health, or some other type of disutility. Since our empirical specification uses monetary losses, we will assume L and e are all measured in dollars. The variable w is the individual's current wealth level.

Preventive effort, e, reduces the probability of a loss (i.e.: $p'(e) \leq 0$). It is important, to distinguish this from the case of self-insurance. Under the self-insurance framework, effort does not affect the probability of a loss, but increasing effort decreases the quantity of a loss if it occurs. In this paper, we only examine prevention as defined in equation (1). We abstract from any issues of how preventive effort affects the loss level. A real-world example of pure prevention is flu shots. An influenza vaccine or 'flu shot' immunizes the patient against a handful strains of the influenza virus, thus reducing the chance the patient will be stricken with influenza. The flu shot, however, does not protect the individual against *all* influenza virus strains. If you do fall ill from an influenza virus strain which was not included in the vaccine, you will experience the same health loss regardless of whether you received the flu shot or not. Thus, the flu shot decreases your probability of getting sick, but does not alter the degree or magnitude of the illness if one does contract a flu strain not included in the vaccine.

3 Theoretical predictions: The effect of Prudence on Prevention

Our hypothesis in this paper is that prudent agents will choose a prevention effort level which is *lower* than that chosen by imprudent agents. This hypothesis stems from the theoretical work of Eeckhoudt and Gollier (2005). Let us assume a similar decision structure as in equation (1)

$$V(e) \equiv p(e)u(w-L-e)+[1-p(e)]u(w-e). \tag{2}$$

Let e_n be the optimal level of preventive effort chosen by a risk neutral agent

$$e_n \equiv max_e \quad p(e)(w-L-e)+[1-p(e)](w-e). \tag{3}$$

If this is the case, then we know that an individual exerts more effort if and only if

$$\begin{aligned} V'(e) &= -\{p(e_n)u'(w-L-e_n)+[1-p(e_n)u'(w-e_n)]\} \\ &- p'(e_n)[u(w-e_n)-u(w-L-e_n)] \geq 0. \end{aligned} \tag{4}$$

Let e_p^* be the optimal level of prevention chosen by a prudent person and e_i^* be the optimal level of prevention chosen by a imprudent individual. Eeckhoudt and Gollier showed that if a risk neutral agent selects an optimal level of preventive effort such that the probability of a loss at this optimum is equal to $\frac{1}{2}$, (i.e.: $p(e_n)=\frac{1}{2}$), then all prudent agents will choose a preventive level less than the risk neutral agent, $e_p^* < e_n$ and all imprudent agents will choose a level of effort greater than the risk neutral agent, $e_i^* > e_n$. The intuition here is that at $p(e_n)=\frac{1}{2}$, a marginal change in e will not influence preferences over the second moment and thus only the agents prudence preferences will affect their choice of e^*. Any differences in risk preferences are irrelevant at $p(e_n)=\frac{1}{2}$.

In our experiment, however, we investigate prevention choices even when $p(e_n) \neq \frac{1}{2}$. In order to do this, we must take into account that increasing e from e_1 to e_2 will decrease $p(e)$. That is, if $e_1 < e_2$, $p(e_1) > p(e_2)$. If $p(e_1), p(e_2) > \frac{1}{2}$, then we know that moving from e_1 to e_2 will increase the variance of the lottery in equation (1). If $p(e_1), p(e_2) < \frac{1}{2}$, then moving from e_1 to e_2 will decrease the variance.

To summarize, if $p(e_n) > \frac{1}{2}$, and an individual is risk averse and prudent, then the effect of risk aversion and prudence operate in the same direction, compelling the agent to choose $e_p^* < e_n$. If $p(e_n) < \frac{1}{2}$, then a risk averse agent will prefer a higher level of effort due to risk considerations, but if they are prudent they will prefer a lower level of effort due to the changing skewness of the distribution. Thus we have opposing effects.

The analysis for a risk loving, prudent person is very similar. If $p(e_n) < \frac{1}{2}$, risk and prudence preferences will induce the agent to decrease e_p^*. If $p(e_n) > \frac{1}{2}$, however, then risk preferences urge the agent to increase e_p^*, but prudence preferences pull them towards decreasing e_p^*. Here again the prediction is ambiguous. Table 1 provides a summary of hypotheses.

Table 1: Hypotheses

If			Then	Where
Risk	Prudence	$p(e_n)$		
Averse	Prudent	$> \frac{1}{2}$	$e^* < e_n$	
Loving	Prudent	$< \frac{1}{2}$	$e^* < e_n$	
Averse	Imprudent	$< \frac{1}{2}$	$e^* > e_n$	
Loving	Imprudent	$> \frac{1}{2}$	$e^* > e_n$	
r	p	$<> \frac{1}{2}$	$e^*_{r,p_i} < e^*_{r,p_j}$	$p_i > p_j$

In the empirical section of the paper, we test these theoretical propositions. The first four rows of Table 1 show the general hypotheses described above. In these tests, risk and prudence preferences operate in the same direction so one would expect a strong effect. In the last row, we attempt to hold constant risk preferences and analyze how prudence preference impact prevention levels.

4 Experimental design and procedure

In our experiment, we measure individual risk preferences, prudence preferences, and levels of preventive effort. Below is a table of our experimental stages.

Table 2: Experimental stages

Stage	Short description
RIAV	20 paired lotteries testing for risk aversion
PRUDA	'Ballot Box': 20 paired lotteries testing for prudence*
PRUDB	'Coin Flip': 2 questions of where to place 0 mean risk to test for prudence**
PREV	10 Decsions on effort to reduce probability of loss
BACK	12 questions on the individuals background characterisitcs

* 10 decision over gains and 10 over losses
** 1 decision over gains and 1 over losses

The experiment was conducted online without any actual payoffs. We offered the chance of a $25 gift certificate to Amazon to induce participation. One hundred twenty one individuals participated in the survey. We dropped 8 individuals from the survey because their responses revealed that the did not fully understand the questionnaire.[1] Thus, we were left with 113 observations.

The average age of the participants was 32.3 years old and average income was $63,450. Sixty four percent of the participants were male and 30% of the survey participants had some education in either economics or business.

4.1 Risk Aversion Questions (RIAV)

There are several accepted ways one can measure risk aversion suitable for a laboratory setting. Examples include eliciting the certainty-equivalent for a given lottery using Vickrey autions or the Becker-DeGroot-Marschak procedure (Becker et al., 1964), or observing subjects' choices over lotteries varying in prizes offered for given probabilities (Binswanger, 1980). We implement a version of the method developed by Holt and Laury (2002). Because the Holt and Laury framework is widely implemented in laboratory experiments and the decicison task involved is relatively transparent, we apply it to evaluate risk aversion.

When applying Holt and Laury's method in RIAV, subjects make 20 choices between the paired lotteries. Our method applied slightly differs from Holt and Laury's. Instead of using positive payoff, subjects decide between lotteries with negative payoffs (losses). It is meaningful to use these kind of lotteries as subjects may exhibit different preferences towards losses compared with gains (Kahneman and Tversky, 1979). We use losses because in the section where individuals choose optimal prevention levels, their prevention level choice reduces the probability of a loss. Thus, estimates of risk preferences over losses are most relevant to this section.

Table 6 in the appendix shows the paired lotteries. Option A gives sure payoffs of $0 in the first question and decreases in two dollar increments until it reaches a loss of $38. For option B, participants face the following lottery in each question: ($0, 50%; -$40, 50%). Thus, individuals who switch to the risky option before option A equals $20 are risk loving, and those who switch to the risky option when Option A equals $20 or more are risk averse. Through this experimental design, the participants reveal their certainty equivalent over this lottery.

[1] 5 individuals were dropped who choose weakly dominated choices [i.e., ($0, .5; -$40, .5)>$0]. 3 more individuals were dropped who had multiple crossover points in the RIAV section.

4.2 Prudence Questions (PRUDA, PRUDB)

In part A of the prudence portion of the survey, subjects are presented with two lotteries, denoted Option A and Option B. Both lotteries have the same mean and variance, but Option A is a mean-variance preserving transformation (MVPT) of Option B (see Table 7). In other words, the lotteries are identical in terms of their first two moments, but one is positively skewed while the other is negatively skewed. For instance, in question 1 on Table 7, the participant must choose between the lotteries (-$10, 75%; -$30, 25%) or ($0, 25%; -$20, 75%). Both lotteries have the same mean (-$15) and variance ($75), but only option B is positively skewed. In our experimental design, each positively skewed lottery is a MVPT of the negatively skewed lottery. According to Menezes et al. (1980), only individuals with $u''' > 0$ will prefer the positively skewed lottery. It is not always the case that a prudent person prefers positively skewed lotteries to negatively skewed lotteries; only when the positively skewed lottery is a MVPT of the other do we know that the individual's lottery choice will reveal their preference for prudence.

We use a ballot box format to visualize lotteries on subjects' decision screens. For an example see Figure 1. For the lottery, (-$10, 75%; -$30, 25%) in question 1 of PRUDA, the ballot box has 75 balls marked with a -$10 and 25 balls marked with a -$30. Questions 1-10 of the PRUDA section ask participants to choose between two lotteries involving losses; questions 11-20 ask participants to choose between lotteries involving gains.

Because we are dealing with preferences based on the third moment of an individual's utility function, one would expect there to be some error. Even very prudent people may not choose the prudent option every time. In order to ensure that our experimental design is robust, we include another prudence section: the 'coin flip' or PRUDB section.

In the coin flip section, individuals are presented with the lottery (-$10, 50%; -$20, 50%). Participants are faced with a choice over what to do with a second risky lottery, x, where $x =$($10, 50%; -$10, 50%). Would they rather play x when they lose 10 in the first lottery or when they lose 20 in the first lottery? A prudent person will play x when they lose only $10 in order to avoid the worst possible out come of -$30. An imprudent individual will play x only when they lose $20. The second question of PRUDB ask the same question except that the initial lottery is over gains, i.e., (+$10, 50%; +$20, 50%).

Mathematically, the two questions in coin flip section are exactly the same as two of the questions in the ballot box test. Thus, we can test whether or not our presentation methodology is influencing individual choices..

4.3 Prevention Questions (PREV)

When we test for prevention subjects are asked to choose an optimal level of effort in order to influence the probability of facing a loss, L. Here, subjects can choose an effort level from an interval between 0 and 9, i.e. $e_{ij} \in \{0, 1, ..., 9\}$. An effort level of 0 costs \$0, and effort level of 1 costs \$1, and so on. The specific questions can be found in Table 8.

When subject i chooses a higher level of prevention in decision j, this will reduce the probability of incurring the loss L (i.e., $p'(e_{ij}) \leq 0 \ \forall j$). However, increasing the effort level involves a higher upfront payment. Further, a higher effort level magnifies the level of the worse possible outcome, $-(L + e_{ij})$. Since prudent individual try to avoid left skewed distributions with large losses, we predict that prudent individuals will choose lower levels of e_{ij}. Since we have evaluated the risk and prudence preferences of our subjects, we can predict how much prevention they will choose.

In many classical utility functions (e.g.: CRRA) people who are risk averse are prudent and those who are risk loving are generally imprudent. Yet this need not be the case. Menezes et al. (1980) state that "...both risk averters and risk preferrers can be downside risk averse. Similarly, individuals with increasing or decreasing utility functions can be averse to a leftward shift of risk. Thus $u'''(x) > 0$ is the only property of $u(x)$ necessary to define the set of downside risk averters." For instance, an individual with the utility function $u(x) = x - x - x^3$ will be risk averse, but imprudent when $x \in (0, \frac{1}{3})$. When an individual has the utility function $u(x) = x^3$, they will be risk loving and prudent .

To verify whether or not prudent individuals choose lower levels of prevention, we examine whether or not prudent individuals do indeed choose lower levels of prevention. Further, we will attempt to control for risk preferences, and then measure within each risk preference category whether or not prudent individuals choose lower levels of prevention than other individuals.

We also test whether or not preferences for prudence (imprudence) lead to less (more) prevention in the case where risk and prudence preference are allowed to have opposing predicted effects on prevention levels. To do this, we group together individuals with the same risk aversion levels as calculated from the RIAV section of the questionnaire. For those with the same risk aversion levels, we test whether or not prudent people select lower prevention levels than imprudent individuals. A regression framework can be implemented in the two prevention scenarios.

$$e_{ij} = \beta_0 + \beta_1 \mathbf{r}_i + \beta_2 \mathbf{r}_i p_i + \epsilon_{ij} \tag{5}$$

In equation (5), the vector $\mathbf{r}$ is a set of dummy variables indicating the individuals risk aversion score and p gives the probability that the individual is prudent. The key parameter is the vector β_2. If $\beta_2 < 0$, than higher prudence levels–conditional on risk preferences–lead to lower levels of prevention. Going forward $\mathbf{r}$ will include 22 dummy variables indicating risk averse behavior and the other indicates risk loving behavior. Using a vector of $\mathbf{r}$ with each individual's particular risk aversion score produces similar qualitative results.

4.4 Background questions (BACK)

At the end of the survey, we also asked the individuals basic questions about their background, such as their age, income, gender and education. Additional questions also asked about their general attitudes towards risk.

5 Results

5.1 Risk Aversion

Figure 2 displays the results from the Risk Aversion (RIAV) portion of the experiment. Risk averse individuals will choose the sure option 11 or more times. A risk loving person will choose the sure option less than 11 times. [2]

In our data, 69.0% of the sample is risk loving over losses and 31.0% of the sample is risk averse over losses. Evidence from the prospect theory literature has shown that individuals are generally risk loving over losses. In fact, Tversky and Kahneman (1992) sample 25 students and find that 87% of the students are risk loving over losses.[3]

5.2 Prudence

The results from the Prudence section are displayed in Table 3.

[2]On the 11th question, an individual is asked whether the prefer (-$20) vs. ($0, 50%; -$40, 50%). We do not allow for indifference and thus a person who prefers -$20 is considered risk averse and the person who prefers the risky lottery with the same expected value is considered risk loving.

[3]The 87% number corresponds to the case where the probability of the loss is greater than one half.

Table 3: Prudence Results by Risk Level

		Total	Loss	Gains
Full Sample	Avg	0.636	0.613	0.655
	SD	0.493	0.278	0.310
	% Prudent	0.531	0.451	0.566
	% Imprudent	0.150	0.195	0.177
Risk Loving	Avg	0.636	0.633	0.638
	SD	0.251	0.278	0.319
	% Prudent	0.551	0.487	0.551
	% Imprudent	0.167	0.192	0.192
Risk Averse	Avg	0.630	0.569	0.691
	SD	0.239	0.277	0.291
	% Prudent	0.486	0.371	0.600
	% Imprudent	0.114	0.200	0.143

Prudent individuals answer prudently 13/20 questions (for the total sample) or 7/10 questions (for gain/loss sections).

In the full sample of the PRUDA section, the average person answered 63.6% of the questions prudently. There are differences between average levels of prudence over gains and losses. The average person answered 61.3% of questions prudently when considering lotteries over losses, but for gains, the average person answers 65.5% of questions prudently. A t-test reveals that this 4.2% difference, however, is not statistically significant at conventional levels ($p < 0.173$).

The average number of questions individuals answer prudently may be a poor proxy for what proportion of the population is truly prudent. Instead, we define a person to be prudent if we can reject the null of them being being 'prudent neutral' at an α of 0.132.[4] In our definition of prudence, 53.1% of the sample is prudent and 15.0% of the sample is imprudent.

The finding that most individuals are prudent holds both for risk loving and risk averse individuals. There is no statistically significant difference between the average number of questions answered prudently by risk averters compared to risk lovers ($p < 0.907$). We do note that for individuals with both types of risk preference have stronger prudence preferences for gains than losses.

[4]A person is considered prudent if they answer 13 or more questions prudently out of 20. When analyzing prudence separately over gains and losses, individuals must answer at least 7 of 10 questions prudently to be considered prudent, which corresponds to an α of 0.172. For imprudent individuals, the cutoffs are ≤ 7 and ≤ 3 questions respectively.)

In order to confirm our results from the 'ballot box' section, we compare individual responses in this section to those in the 'coin flip' section. The results are displayed in Table 4. We find similar results across both the ballot box and coin flip sections, however the average level of prudence is higher when we use the coin flip.

Table 4: Prudence Results for the Ballot Box and Coin Flip Sections

Type of Question	Total	Risk Loving	Risk Averse	CRRA: $(-1 < \alpha < 0)$
Losses(Ballot Box)	0.613	0.633	0.569	0.626
Losses(Coin Flip)	0.796	0.795	0.800	0.849
Gains(Ballot Box)	0.655	0.638	0.691	0.626
Gains(Coin Flip)	0.814	0.795	0.857	0.792
Total (Ballot Box)	0.634	0.636	0.630	0.626
% Prudent (Ballot Box)	0.531	0.551	0.486	0.566
% Imprudent (Ballot Box)	0.150	0.167	0.114	0.170

Two questions in the ballot box section were mathematically identical to those in the coin flip section. When we test whether or not the answers given by individuals are consistent across the two sections, we reject the null that the answers in the coin flip section are uncorrelated with their mathematical equivalents in the ballot box section ($p < 0.001$).

To further test the consistency of our results, two questions in the ballot box section were identical in both the gain and the losses section. The only change was that we switched the order in which the lotteries were presented. For losses, 62.9% of individuals answered the identical questions the same; for the gains section this figure was 69.0%. It should not be surprising that these figures are not at 100% or even 90%. Our experiment asks individuals to compare lotteries with the same mean and variance. Thus, the experimenter must expect a some degree of error on the part of the participants. Nevertheless, we strongly reject the null that individuals are answering these questions randomly by conducting a t-test for both losses ($p < 0.003$) and gains ($p < 0.001$).

We also test whether or not having an economics or business background affects prudence preferences. Those who majored in economics were more likely to answer questions prudently for losses ($p < 0.010$) but were no more likely to answer prudently over gains ($p < 0.312$). This could be explained by underlying differences between the two groups. It could also be the case that non-economics majors had a steeper learning curve to understanding these questions since the prudence questions with losses were presented first.

In summary, we have found that 53.1% of individuals are prudent while 15.0% of individuals are not. The proportion of prudent individuals is similar across risk lovers and risk averters. Responses to the prudence questions are robust to a change in the framing of the question (i.e., ballot box vs. coin flip presentation) as well as the order in which the lotteries are presented.

Other papers have used certainty equivalents in order to measure prudence. For instance, Eisenhauer and Ventura (2003) measure absolute and relative prudence by fitting a constant relative risk aversion function (CRRA) to a single question about the willingness to pay for a 50/50 gamble.[5]. If we assumed a utility function of the form $u(x) = \frac{x^{1-\theta}}{1-\theta}$, then $u''' = \frac{\theta(1+\theta)}{x^{\theta+2}}$. If $x > 0$, then an individual is imprudent when $\theta \in (-1, 0)$ and prudent otherwise.

In the RIAV section, we examine individuals for whom the fitted value of θ is between -1 and 0. Under expected utility theory, we would predict that these individuals should act imprudently and should be more likely to choose the negatively skewed lotteries in our prudence sections. The result of this analysis are shown in Table 4.

We see that the majority of individuals whom EUT predicts would be imprudent under CRRA are actually prudent in our experiment. Individuals who are risk loving with $\theta \in (-1, 0)$ answer 62.6% of questions prudently. Further, we classify only 17.0% of these individuals as imprudent compared to 56.6% who are classified as prudent. From these results, we conclude that simply fitting a CRRA function to a certainty equivalents questions does not accurately characterize an individuals prudence preferences. We propose that our non-parametric measure of prudence better characterizes how individuals view skewed lotteries.

5.3 Prevention

One question remains: do prudent individuals select lower levels of prevention? In order to test this hypothesis, we first regress the level of prevention chosen in each question on the level of prudence. The results are in Table 5. We use the number of questions an individuals answered prudently as a proxy for their level of prudence. Since the prevention section involves making payments to reduce the probability of a loss, we only take into account prudence questions over losses. Using categorical dummy variables for prudent, imprudent, and prudent neutral individuals gives similar qualitative results.

We first examine the constant term. The average prevention level selected was greater

[5]The actual question asked is "You are offered the opportunity of acquiring a security permitting you, with the same probabilities, either to gain 10 million lire or to lose all the capital invested. What is the most you are prepared to pay for this security?"

than the one that maximized the expected value for a risk neutral person (i.e., $\frac{1}{n}\Sigma_i e^*_{ij} > e_n \; \forall j$). This is likely due to the experimental design. For questions 1-4, e_n=3; for questions 5-6 e_n= 2 or e_n=3; and for questions 7-8, e_n=4. If an survey participant wanted to choose the median prevention level, they would select e^*=4 or e^*5. We do see individual choices congregating around these values. For questions 5-6, however, survey respondents generally choose e^* to be lower than for the other questions.

Now we turn to the coefficient on $Prudence$. Across all 8 prevention questions, we find a similar trend. Prudence decreases prevention levels in all 8 regressions but not in a statistically significant manner. On average, the Prudence coefficient is -0.043. This means that on a scale from \$0 to \$9, individuals who prefer prudent lotteries every time contribute \$0.43 less towards prevention than an individual who always prefers imprudent choices. We cannot reject the null hypothesis that $Prudence$ has no impact on prevention even across all 8 prevention questions ($p < 0.592$). Still, this consistency of the negative coefficient across all 8 specification provides some suggestive evidence that higher levels of prudence lead to less prevention, even if this effect is small in magnitude.

Section 3 of the paper noted that both risk and prudence preferences should influence the preferred level of prevention e^*. Higher levels of risk aversion should decrease e^* when $p(e_n) > \frac{1}{2}$ and increase e^* when $p(e_n) < \frac{1}{2}$. In two of four prevention questions where $p(e_n) > \frac{1}{2}$, higher levels if risk aversion does decrease e^*; in zero of four prevention questions where $p(e_n) < \frac{1}{2}$, higher levels of risk aversion increases e^* . Further, none of these results are statistically different from 0 at the 5% level. When we examine the interaction of the prudence and the dummy variables for risk aversion and risk loving, we find very little predictive power. None of the interaction coefficients were statistically different from 0 at the 5% level.

Overall, we did find some suggestive evidence that higher levels of prudence may decrease prevention, but these results are far from conclusive.

6 Conclusion

Prudence has been shown theoretically to be an important determinant of precautionary savings, asset allocation and optimal prevention levels. However, empirical measures of of prudence have been scare and generally identify prudence through assumption with respect to the functional form of the utility function.

This paper takes a non-parametric approach to reveal a more comprehensive understanding of individual's preferences for prudence. We find that on average 53.1% of individuals are prudent and 15% of individuals are imprudent. Risk averse or risk loving behavior does not seem to impact the probability that an individuals will be prudent. Although participants respond more prudently when questions were asked using the coin flip presentation as opposed to ballet box presentation, participants did answer questions consistently across specifications.

In order to calculate prudence, previous research has fit standard utility functions to participant certainty equivalent responses responses. Our results contradict the validity of this methodology. When we isolate imprudent individuals as predicted by CRRA certainty equivalents, we find only 17.0% are actually imprudent compared to 56.6% who are prudent. We propose that our non-parametric measure of prudence better characterizes the manner in which individuals view skewed lotteries.

We did find some suggestive evidence that prudent individuals choose lower levels of prevention. On a scale from $0 to $9, prudent individuals choose to $0.43 less of prevention than imprudent individuals. Although this result was small in magnitude and not statistically significant, in all 8 questions more prudent individuals choose less prevention.

One limitation to this approach is that we do not measure the strength of an individuals' preferences for prudence. Because we measure preferences over the third derivative of the utility function, precisely estimating the magnitude of prudence is difficult. In the future we aim to estimate a prudence premium over skewed lotteries. Future research should also try to take these findings out of the experimental setting. Utilizing the prudence measures in this paper, researchers should be able to determine whether or not prudent individuals are more likely to get a flu shot or select different investment allocations. This paper gives suggestive evidence that prudent individuals like Aristotle may prefer lower levels of prevention and thus may be less likely to get flu shots.

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A Appendix

Table 5: Prevention and Prudence Regressions

		$p(e_n) > .5$				$p(e_n) < .5$			
Specification	Variable	1	3	5	7	2	4	6	8
1	Prud	-0.054	-0.049	-0.066	-0.044	-0.051	-0.038	-0.037	-0.043
		(0.084)	(0.077)	(0.081)	(0.084)	(0.083)	(0.071)	(0.081)	(0.079)
	Constant	5.640	6.019	4.575	4.463	4.554	5.030	3.767	4.281
		(0.567)	(0.518)	(0.548)	(0.563)	(0.559)	(0.478)	(0.545)	(0.533)
2	(RA)(Prud)	0.009	-0.020	0.160	0.187	0.070	0.060	0.193	0.145
		(0.154)	(0.141)	(0.146)	(0.151)	(0.152)	(0.130)	(0.146)	(0.144)
	(RL)(Prud)	-0.069	-0.053	-0.149	-0.150	-0.107	-0.089	-0.144	-0.127
		(0.102)	(0.094)	(0.097)	(0.100)	(0.101)	(0.086)	(0.097)	(0.095)
	RA	0.019	0.148	-1.191	-2.172	-1.129	-1.188	-2.210	-1.657
		(1.202)	(1.100)	(1.141)	(1.179)	(1.185)	(1.010)	(1.139)	(1.122)
	Constant	5.590	5.939	4.908	5.194	4.934	5.448	4.514	4.831
		(0.706)	(0.646)	(0.670)	(0.693)	(0.696)	(0.593)	(0.669)	(0.659)

Table 6: Paired lotteries in stage RIAV

Question	Option A	Option B	E(A)-E(B)
1	$0	($0, 50%; -$40, 50%)	$20
2	-$2	($0, 50%; -$40, 50%)	$18
3	-$4	($0, 50%; -$40, 50%)	$16
4	-$6	($0, 50%; -$40, 50%)	$14
5	-$8	($0, 50%; -$40, 50%)	$12
6	-$10	($0, 50%; -$40, 50%)	$10
7	-$12	($0, 50%; -$40, 50%)	$8
8	-$14	($0, 50%; -$40, 50%)	$6
9	-$16	($0, 50%; -$40, 50%)	$4
10	-$18	($0, 50%; -$40, 50%)	$2
11	-$20	($0, 50%; -$40, 50%)	$0
12	-$22	($0, 50%; -$40, 50%)	-$2
13	-$24	($0, 50%; -$40, 50%)	-$4
14	-$26	($0, 50%; -$40, 50%)	-$6
15	-$28	($0, 50%; -$40, 50%)	-$8
16	-$30	($0, 50%; -$40, 50%)	-$10
17	-$32	($0, 50%; -$40, 50%)	-$12
18	-$34	($0, 50%; -$40, 50%)	-$14
19	-$36	($0, 50%; -$40, 50%)	-$16
20	-$38	($0, 50%; -$40, 50%)	-$18

Table 7: Paired lotteries in stage PRUDA

	Option A				**Option A**				Prudent
Question	P(X_1)	X_1	P(X_2)	X_2	P(X_1)	X_1	P(X_2)	X_2	Option
1	75%	-$10	25%	-$30	25%	$0	75%	-$20	B
2	25%	-$5	75%	-$25	75%	-$15	25%	-$35	A
3	90%	-$19	10%	-$29	10%	-$11	90%	-$21	B
4	20%	$0	80%	-$20	80%	-$12	20%	-$32	A
5	5%	-$1	95%	-$21	95%	-$19	5%	-$39	A
6	80%	-$17	20%	-$42	20%	-$2	80%	-$27	B
7	90%	-$13	10%	-$23	10%	-$5	90%	-$15	B
8	90%	-$21	10%	-$1	10%	-$37	90%	-$17	A
9	75%	-$15	25%	-$35	25%	-$5	75%	-$25	B
10	90%	-$11	10%	-$21	10%	-$3	90%	-$13	B
11	10%	$11	90%	$21	90%	$19	10%	$29	B
12	95%	$19	5%	$39	5%	$1	95%	$21	A
13	10%	$3	90%	$13	90%	$11	10%	$21	B
14	10%	$37	90%	$17	90%	$21	10%	$1	A
15	80%	$12	20%	$32	20%	$0	80%	$20	A
16	25%	$5	75%	$25	75%	$15	25%	$35	B
17	10%	$5	90%	$15	90%	$13	10%	$23	B
18	75%	$15	25%	$35	25%	$5	75%	$25	A
19	20%	$2	80%	$27	80%	$17	20%	$42	B
20	25%	$0	75%	$20	75%	$10	25%	$30	B

Table 8: Effort choices and corresponding lotteries in stage PREV

Q1	*e*	0	1	2	3	4	5	6	7	8	9
	P(Losing $30)	0.99	0.80	0.70	0.65	0.63	0.62	0.61	0.60	0.60	0.60
Q2	*e*	0	1	2	3	4	5	6	7	8	9
	P(Losing $30)	0.49	0.31	0.20	0.15	0.13	0.12	0.11	0.10	0.10	0.10
Q3	*e*	0	1	2	3	4	5	6	7	8	9
	P(Losing $40)	0.99	0.80	0.70	0.65	0.63	0.62	0.61	0.60	0.60	0.60
Q4	*e*	0	1	2	3	4	5	6	7	8	9
	P(Losing $40)	0.49	0.31	0.20	0.15	0.13	0.12	0.11	0.10	0.10	0.10
Q5	*e*	0	1	2	3	4	5	6	7	8	9
	P(Losing $20)	0.99	0.80	0.70	0.65	0.63	0.62	0.61	0.60	0.60	0.60
Q6	*e*	0	1	2	3	4	5	6	7	8	9
	P(Losing $20)	0.49	0.31	0.20	0.15	0.13	0.12	0.11	0.10	0.10	0.10
Q7	*e*	0	1	2	3	4	5	6	7	8	9
	P(Losing $30)	0.94	0.80	0.73	0.65	0.61	0.58	0.56	0.55	0.54	0.54
Q8	*e*	0	1	2	3	4	5	6	7	8	9
	P(Losing $30)	0.44	0.30	0.23	0.15	0.11	0.08	0.06	0.05	0.04	0.04

Figure 1: Sample question in stage PRUD