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How do risk attitudes affect measured confidence?

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How do risk attitudes affect measured confidence?

Zahra Murad^{a, b}, Martin Sefton^a and Chris Starmer^a

November 2014

Abstract

We examine the relationship between confidence in own absolute performance and risk attitudes using two elicitation procedures: self-reported (non-incentivised) confidence and an incentivised procedure that elicits the certainty equivalent of a bet based on performance. The former procedure reproduces the “hard-easy effect” (overconfidence in easy tasks and underconfidence in hard tasks) found in a large number of studies using non-incentivised self-reports. The latter procedure produces general underconfidence, which is significantly reduced, but not eliminated when we filter out the effects of risk attitudes. Finally, we find that self-reported confidence correlates significantly with features of individual risk attitudes including parameters of individual probability weighting.

Keywords: Overconfidence, Underconfidence, Experiment, Risk Preferences

JEL: C91, D81

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1. Introduction

A large literature dating back to the 1970s documents systematic biases in individuals' confidence assessments of their own performance. In this paper we report an experiment investigating possible relationships between measured confidence and risk attitudes.

Our study has two primary motivations. One flows from an apparent clash between the stylized findings from the psychological literature and more recent evidence emerging from experimental economics. A large volume of research in psychology suggests that individuals have predictable tendencies towards either overconfidence or a hard-easy effect (over-estimating own performance in hard tasks and under-estimating it in easy tasks). By contrast, more recent research in experimental economics has found either much less confidence miscalibration or, when it occurs, strikingly different patterns of miscalibration (we discuss the evidence in more detail in the next section). What might account for this difference? One distinctive feature of much of the newer literature is that it employs various (financial) incentive mechanisms to motivate revelation of confidence, whereas the psychology studies rely on non-incentivised self-reported confidence. So, one possible diagnosis is that the newer evidence provides more accurate confidence measurement as a consequence of incentivised revelation techniques. In this paper, however, we investigate another possibility: that some of the differences between findings of economists and psychologists may be a consequence of biases in measured confidence induced by incentive mechanisms which fail to control for the influence of individual risk attitudes.

Our second motivation is to explore the possibility that confidence judgements may be intrinsically related to risk attitudes. It seems intuitively plausible that there could be a positive association between individuals being more confident and being more willing to take risks. For example, overconfidence about own abilities and a willingness to take risks might be common consequences of particular personality traits (e.g. egotism) or emotional states or dispositions (e.g. optimism). While these considerations suggest a possible linkage between individual confidence assessment and risk attitudes, as far as we know, there is no existing evidence to support it.

In pursuit of these objectives, we elicit confidence via two distinct methods and we also independently measure individual risk attitudes. One of our confidence measurement tools is a non-incentivised tool designed to be analogous to procedures that have been used extensively in psychological research; the other is an incentivised choice based procedure. We designed the latter to be incentive compatible for revelation of confidence for risk neutral subjects but, in common with other incentive mechanisms that have been used in the recent literature, our

procedure will result in biased confidence measurements for non-risk neutral subjects. Thus, we use elicited risk attitudes to adjust incentivised confidence measures for departures from risk-neutrality. We also examine whether individual risk attitudes predict self-reported (non-incentivised) confidence judgements. Section 3 describes our design in more detail.

In Section 4 we present our results. There are three primary findings. First, our two tools produce markedly different patterns of confidence miscalibration, mimicking the stylised facts of existing research (the non-incentivized tool reproduces the familiar hard-easy effect, while our incentivised tool reveals general underconfidence). Second, when we filter out the effects of risk attitudes on incentivised measurements of confidence, we find that measured miscalibration is much reduced. This shows that incentivised mechanisms for confidence elicitation can be biased in the absence of suitable controls for risk preferences. Finally, we find that confidence as measured by the non-incentivized self-reports correlates significantly with features of individual risk attitudes including parameters of individual probability weighting functions. Moreover the directions of association are intuitively plausible: for example, reported confidence is positively associated with risk parameters that imply greater willingness to take risk. Section 5 discusses these results and concludes.

2. Literature Review

There is a large literature in psychology on biases in individual assessments of their own abilities, both relative to others' and in absolute terms. Findings of overconfidence in own performance relative to that of others (e.g. Svenson 1980) has motivated many studies by experimental economists on the relationship between relative confidence, relative ability, and willingness to take risks in strategic environments (e.g. Camerer & Lovallo 1999; Hoelzl & Rustichini 2005; Moore & Cain 2007; Niederle & Vesterlund 2007). In this paper, we focus on the calibration of own *absolute* performance. This is the more suitable measure given our purpose of studying the relationship between confidence judgements and risk attitudes since both are in the domain of individual choice. By contrast, miscalibration of relative performance may reflect miscalibration of own performance, or of the performance of others, and its measurement may be complicated by strategic and/or social comparison concerns.

Early studies by psychologists on individuals' self-assessment of own performance document systematic miscalibration, usually towards overconfidence or a hard-easy effect (Fischhoff, Slovic & Lichtenstein 1977; Lichtenstein & Fischhoff 1981; Lichtenstein, Fischhoff & Phillips, 1982; see Keren 1991 or Alba & Hutchinson 2000 for a review). In a typical study (e.g. Fischhoff et al. 1977), individuals are given quiz questions and asked to give an answer and an

assessment of the chances of their answer being correct. A common finding is that on questions where the success rate is high (say, 90% of individuals correct) average confidence is substantially lower than the success rate, whereas in questions with a lower success rate (say, 60% get the correct answer), average confidence is substantially higher than the success rate.¹

Confidence about own abilities has been shown to affect many important economic decisions such as trading behaviour (Biais, Hilton, Mazurier & Pouget 2005), job search (Dubra 2004), investment in education (Dunning, Heath & Suls 2004) and bargaining behaviour in binding arbitration (Dickinson 2006), and given the findings from psychologists' measurement of confidence it is not surprising that economists have begun to incorporate overconfidence into economic models (Compte & Postlewaite 2004; Gervais, Heaton & Odean 2011; Herz, Schunk & Zehnder 2014).

However, recent research by experimental economists has revealed rather different patterns in (absolute) confidence compared to the earlier psychology literature.² One of the first papers in experimental economics to study absolute confidence miscalibration is by Blavatskyy (2009). In his experiment, subjects answer a set of 10 multiple choice quiz questions before choosing between two payment schemes. Either one question is selected at random and the subject receives a payoff if he or she has answered this question correctly, or the subject receives the same payoff with a stated probability set by the experimenter to be equal to the percentage of correctly answered questions (although the subject does not know this is how the probability is set). Subjects could also indicate indifference. He finds that the majority choose the second payment scheme, which he interprets as reflecting underconfidence. He also elicits risk attitudes in a separate part of the experiment but finds no significant relationship between these risk attitudes and choices of payment scheme. In our study, by contrast and as explained below, *we do* find significant correlations between risk attitudes and confidence.³

¹ Asking respondents for non-incentivised assessments of their probability of success is a simple and transparent tool for eliciting beliefs. The approach has been used in the field with evidence of overconfidence and miscalibration found among weather forecasters (Murphy & Daan 1984), sports experts forecasting sports results (Andersson, Edman & Ekman 2005) and economists (Braun & Yaniv 1992) and managers (Aukutsionek & Belianin 2001) making economic forecasts.

² A related literature in psychology has challenged the interpretation of findings from miscalibration studies, arguing that observed overconfidence and the hard-easy effect may be partly artefacts of the confidence elicitation tools and/or methods used to analyse data, rather than biases in individual information-processing (see Olsson 2014 for a review).

³ There are various differences between our methodologies that might explain this key difference in findings. For example, Blavatskyy (2009) does not directly elicit confidence measures, as we do, but rather infers underconfidence from the choice of payment scheme. As such, his measure of an individual's confidence is rather coarse, potentially limiting his analysis of the relation between individual risk attitudes and confidence. Our measurement of risk attitudes also allows us to distinguish attitudes to consequences and attitudes to chance.

In a related contribution, Urbig, Stauf & Weitzel (2009) elicit confidence about own performance over a set of 10 multiple choice quiz questions. They use an incentivized mechanism that elicits confidence via probability equivalents for bets based on own performance. In their data the average elicited probability equivalent is extremely close to the actual rate of success. Both Blavatsky (2009) and Urbig et al. (2009) note the difference between their findings and those from the earlier psychology literature, and speculate that the difference may be due to the introduction of incentivized elicitation devices. However, neither study contains a benchmark treatment for comparing the elicited confidence with a non-incentivized tool. Our study includes such a comparison.

Clark & Friesen (2009) study subjects' confidence in relation to two types of real effort task involving verbal and numerical skills. They study calibration over a set of tasks using either non-incentivized self-reports or quadratic scoring rule (QSR) incentives. They find underconfidence more prevalent than overconfidence and better calibration with incentives. Moreover, they find that underconfidence is greatest among those using greater effort. One potential limitation of their analysis, however, is that, unless subjects are risk neutral, QSR may result in biased measurements of confidence (we return to this point below in more detail).

A potentially significant feature of all three of the experiments discussed in the last three paragraphs is that they elicit confidence in relation to performance across *sets* of tasks. By contrast, much of the earlier psychological literature investigating confidence calibration assessed it with reference to performance in *single tasks*. This may be a significant distinction because there is evidence that miscalibration varies between measurements based on single versus sets of tasks. For example, Gigerenzer, Hoffrage & Keimling (1991), Liberman (2004) and Griffin & Brenner (2008) report that when beliefs are elicited about aggregate performance in sets of tasks most subjects are either well-calibrated or underconfident whereas overconfidence is evident when elicitation is at the single task level. We study confidence on a single task level. Hence our evidence is more directly comparable with the original confidence calibration studies.

Hollard, Massoni & Vergnaud (2010) elicit absolute confidence on a disaggregate task-level and compare confidence in visual perception and quiz tasks comparing three elicitation tools: non-incentivized self-reports; the QSR; and the Becker-deGroot-Marschak (BDM) mechanism. They find highest overconfidence in the non-incentivized self-reports followed by BDM and then QSR. BDM-elicited confidence being higher than QSR-elicited confidence is consistent with the effects of risk aversion, but since they do not elicit risk attitudes we cannot tell whether that difference is caused by risk attitudes or something else, such as differences in

understanding of the elicitation procedures. With our methodology we will be able to identify the extent to which elicited confidence is affected by risk attitudes.

Our study is also related to a growing literature on elicitation of subjective beliefs. Offerman, Sonnemans, van de Kuilen & Wakker (2009), Trautmann & van de Kuilen (2014) and Harrison, Martinez-Correa, Swarthout & Ulm (2013) elicit subjects' beliefs about uncertain events in a two-step process, using estimates of individual risk attitudes to filter out the effect of risk attitudes from measured beliefs. Our experiment also estimates risk attitudes to filter out the effect of risk attitudes from beliefs. The key difference is that we are concerned with biases in subjective estimates of confidence in own performance (not biases in assessments of naturally determined chance events). A second difference from these studies is that we use the parametric method developed by Fehr-Duda, Gennaro & Schubert (2006) to estimate individual risk attitudes under rank-dependant utility (RDU) theories. This method gives us a rich measure of risk attitudes which separates attitudes to consequences from attitudes to probabilities. In our analysis, we use the measured risk attitudes for two distinct purposes: First, by comparing risk-adjusted to unadjusted confidence we are able to track an effect of risk attitudes on confidence elicited using our incentivized mechanism; second, by relating measured risk attitudes to (non-incentivised) self-reported confidence we are able to test for an intrinsic relationship between confidence and risk attitudes.

Our second purpose, just mentioned, connects with previous studies that have investigated links between individual characteristics and confidence. These have mostly focused on gender differences and find that women are less confident than men in relative terms but not in absolute terms (Clark & Friesen 2009; Biais et al. 2005; Lundeberg, Fox, Brown & Elbedour 2000). More recently, there has been considerable interest in how personality traits and economic preferences interact. It has been found that personality traits such as openness and extraversion predict confidence and overconfidence respectively (Schaefer, Williams, Goodie & Campbell 2004), neuroticism and cognitive ability predict risk taking (Rustichini, DeYoung, Anderson & Burks 2012), and narcissism predicts higher confidence and more willingness to bet on one's own performance (Campbell, Goodie & Foster 2004). It has also been found that personality traits complemented by risk preferences are successful in predicting many life outcomes such as health, earnings and education (Becker, Deckers, Dohmen, Falk & Kosse 2012). None of these studies, however, report how risk attitudes are correlated with elicited confidence at the individual level. This is a significant gap which our study seeks to address.

3. Methods

We measure confidence about own performance in the context of a standard quiz framework. Subjects respond to a series of two-item multiple-choice questions each of which asks them to judge which of a pair of cities has the highest population. For each quiz response, we elicit a measure of confidence. We employ two different procedures for measuring confidence implemented in two treatments (between subjects design). As a benchmark treatment we elicit confidence using self-reported non-incentivised confidence assessments. In this treatment, alongside each quiz answer the subject completed the statement: "I am ___% confident that my answer is correct". In the other treatment we infer confidence from responses to a new incentivised procedure which we introduce now in Section 3.1.

3.1. Inferring Confidence and Eliciting Risk Preferences

Our incentivised measurement tool elicits confidence about own performance using a choice list format.⁴ Figure 1 illustrates the tool. At the top of figure, the subject has to choose which of two cities has the higher population. They are then required to complete the table below the quiz question choosing either A or B in each of the 20 rows.

[Insert Figure 1 around here]

Given the construction of the table, subjects are expected to choose Option B in the first row and Option A in the last row. At some point they will likely switch from option B to A, and this switchpoint is used to measure their confidence in their answer. For example, suppose a subject thinks she has a 67% chance of being correct. Her expected earnings from option A are £6.70 and so if she wants to maximise her expected earnings she should switch from B to A at row 8. We will refer to these switchpoints as *certainty equivalents (CE)* and under expected value maximisation (EV) the CE can be interpreted as revealing an individual's subjective probability of success ($\pm 2.5\%$).

More generally, the CE picks up some mix of assessment of their chances of success with (possibly several) aspects of risk attitudes including non-linear attitudes to consequences and

⁴ A choice list elicitation procedure was used as early as Cohen, Jaffray & Said (1987) to elicit risk preferences. Andersen, Harrison, Lau & Rutstrom (2006) and Isoni, Loomes & Sugden (2011) extensively discuss the advantages and disadvantages of using choice lists as elicitation tools. We use choice lists mainly because of the clear interpretable framework of the decision environment (the value of betting on one's own answer) and the relative ease with which subjects may see that truthful revelation is in their best interest.

probabilities. For example, if the subject is a risk averse expected utility maximiser she will switch at a later row. If we were to incorrectly assume that this subject makes choices according to the EV model, we would interpret this later switchpoint as indicating a low subjective probability of success. In this case our estimate of the subject's confidence would be biased and, even if the individual is perfectly calibrated in that her subjective probability accurately reflects her underlying performance, we would incorrectly record underconfidence. Similarly, if choices are made based on non-linear attitudes to probabilities, we would obtain biased measures of confidence if we were to infer confidence through the lens of a model that fails to incorporate these attitudes, and as a result we would attribute systematic miscalibration to well-calibrated subjects.

To allow for non-linear attitudes to consequences and/or probabilities we infer confidence from CE's using one of the most common and parsimonious specifications for risk preferences, Rank Dependent Utility (RDU) theory. Under RDU, there should be a unique switchpoint at which the utility of the certainty equivalent will be (approximately) equal to the value of the lottery.⁵ Hence, under the RDU model (which contains expected utility and expected value theories as special cases) we may write:

$$U(CE_i) = U(\pounds 10)w(Conf_i) + U(\pounds 0)(1 - w(Conf_i)) \quad (1)$$

where CE_i is an individual's certainty equivalent for question i , $U(\cdot)$ is a utility function defined on money payoffs and $w(\cdot)$ is an RDU probability weighting function. In expression (1) we treat confidence as a subjective probability judgement that underlies choices, but may be prone to biases and miscalibration. The function $w(\cdot)$ is then interpreted as capturing attitudes to chance distinct from miscalibration.⁶ Rearranging equation (1) we obtain the probability that a subject assigns to being correct in question i , denoted $Conf_i$, as:

$$Conf_i = w^{-1}\left(\frac{U(CE_i) - U(\pounds 0)}{U(\pounds 10) - U(\pounds 0)}\right) \quad (2)$$

Under the EV model both the value function and the probability weighting function are linear so confidence can be inferred directly from an observed CE as $Conf_i = CE_i/10$. Estimation under the RDU model requires knowledge of both the utility function and the probability weighting function.

⁵ For compactness, the discussion now proceeds as if CE is revealed accurately by our procedure but the reader should keep in mind that there is, of course, an element of approximation.

⁶ In the literature on prospect theory, probability weights are sometimes interpreted as reflecting misperception of underlying probabilities, sometimes reflecting subjective attitudes to chance, and sometimes a mixture of the two. For discussion and a formalisation following the latter mixed approach, see Abdellaoui, L'Haridon & Paraschiv (2011). For a thorough discussion of prospect theoretic models see Wakker (2010).

In both treatments, we estimate individual risk attitudes from a series of lottery choices. We use these estimates to filter out the effects of risk attitudes on elicited confidence in our incentivized procedure and to study the relationship between individual confidence and risk attitude. For the purpose of estimating $U(\cdot)$ and $w(\cdot)$, we use a simple and easy to understand procedure introduced in Fehr-Duda, Gennaro & Schubert (2006) and successfully employed to estimate utility function and probability weighting function parameters in several subsequent studies (including: Bruhin, Fehr-Duda & Epper 2010; Fehr-Duda, Bruhin, Epper & Schubert 2010; and Epper, Fehr-Duda & Bruhin 2011). Because it uses a choice list elicitation task which is very similar in structure to our confidence elicitation task, it is particularly well suited to our study as its use minimises the cognitive load involved in subjects learning how to respond to the two types of task.

[Insert Figure 2 around here]

The procedure requires each subject to complete 25 tables of the form given in Figure 2. Each table consists of 20 rows, where each row is a choice between a two-outcome lottery and a guaranteed amount of money, with the guaranteed amount of money decreasing from the high outcome to the low outcome of the lottery in equal increments moving down the rows. The subject's certainty equivalent, CE_L , of lottery L can be written as in (3), where the high prize of the lottery x_{1L} occurs with probability p_{1L} and the low prize of the lottery x_{2L} occurs otherwise:

$$U(CE_L) = U(x_{1L})w(p_{1L}) + U(x_{2L})(1 - w(p_{1L})). \quad (3)$$

We use the switching point from choosing the guaranteed amount (Option B) to the lottery L (Option A) as our estimate of the subject's certainty equivalent of the lottery.

To estimate $U(\cdot)$ and $w(\cdot)$ we first specify functional forms for utility and probability weighting functions. We follow Bruhin, Fehr-Duda, & Epper (2010) in their choice of flexible and interpretable functions which have been widely used elsewhere in the empirical literature. On this basis we use the power function for the utility function:

$$U(x) = x^\alpha. \quad (4)$$

This specification is parsimonious in modelling risk attitudes via a single curvature parameter, α , and has been shown to provide a good fit to a wide range of choice data. To allow for non-linear probability weighting in the estimation of RDU parameters, we use the linear-in-log-odds function of Goldstein & Einhorn (1987):

$$w(p) = \frac{\beta p^\gamma}{\beta p^\gamma + (1-p)^\gamma}. \quad (5)$$

This specification is credited with providing a good account of individual heterogeneity (Wu, Zhang & Gonzalez 2004) and its two parameters have the advantage of having clear intuitive interpretations (Lattimore, Baker & Witte 1992; Bruhin, Fehr-Duda & Epper 2010): the parameter β captures ‘elevation’ of the probability weighting function (with greater β reflecting more ‘optimism’); the parameter γ controls curvature (for $\gamma < 1$, the smaller is γ , the stronger is the deviation from linearity).

Finally, operationalizing the model requires specification of some stochastic element in the decision process. Following Epper, Fehr-Duda & Bruhin (2011) we assume that the observed switching point, \widehat{CE}_L , is given by:

$$\widehat{CE}_L = CE_L + \epsilon_L, \quad (6)$$

where the error terms are independent draws from a normal distribution with zero mean. Heteroskedasticity in the error variances across the elicitation tables is accounted for, as in Fehr-Duda, Bruhin and Epper (2011), by assuming the standard deviation of the distribution of the error term, v_L , is proportional to the difference between the guaranteed amounts in option B as one moves down the rows of the table. Hence, $v_L = v(x_{1L} - x_{2L})$, where v denotes an additional parameter to be estimated. The normalized standard deviation v , and the parameters of $U(\cdot)$ and $w(\cdot)$ are then obtained by maximum likelihood estimation.

3.2. Experimental Procedures

The experiment consisted of two parts where Part 1 was the same for all the subjects and Part 2 varied according to the treatment. We use Part 1 for eliciting subjects' utility and probability weighting functions. The 25 lotteries of Part 1 are summarized in Table 1 and were adapted from Fehr-Duda, Gennaro & Schubert (2006). The order of the lotteries was randomized across subjects.

After completing Part 1 of the experiment, subjects were asked to answer quiz questions where they had to judge which of two cities have the highest population.⁷ The quiz can be seen in Appendix A. They could earn £0.50 for each correct answer. In the Reported Confidence treatment, subjects were asked to provide a confidence judgement for each question by filling in the blank "I am ___% confident that my answer is correct". In the Inferred Confidence treatment, we introduced our new elicitation tool where subjects were asked to complete a table as in Figure 1. They had to complete one table for each quiz question.

⁷ We did not randomize the order of risk and confidence elicitation since we wanted to ensure a common experience prior to confidence measurement across treatments.

After answering all quiz questions and providing their confidence levels (either by reporting or filling in the table), subjects were asked to complete a questionnaire while we checked their answers. Via this questionnaire, we elicited a variety of things including basic demographic information and a measure of ambiguity attitudes using classic (non-incentivized) Ellsberg's urn problems.⁸ Full details of the questionnaire are provided in Appendix B.

At the end of the experiment, we used a random incentive system to pay subjects.⁹ Subjects were paid based on one randomly drawn row in one randomly drawn table in one randomly drawn part of the experiment. We used physical objects (dice, numbered balls and poker chips) to make the independence of the randomization devices salient, and we explained the randomization procedures with simple examples and diagrams. The full experimental instructions are available on request.

[Insert Table 1 around here]

The experiment was conducted at the University of Nottingham, CeDEx lab in 2011. Subjects were recruited using ORSEE (Greiner 2004). In total 86 subjects participated; 40 in the Inferred Confidence treatment (25 male), and 46 in the Reported Confidence treatment (23 male). The experiment was conducted in pen and paper format with subjects seated in cubicles. The experiment lasted approximately 1 hour and the average payment to a participant was £9.

4. Results

We structure the results under three subheadings. In Section 4.1, we compare and contrast the data on average confidence elicited in the two treatments. In Section 4.2, we present our findings on individual risk attitudes and risk-adjusted confidence. Finally, in Section 4.3, we present results looking at the relationship between risk attitudes and reported confidence.¹⁰

⁸ We included a basic tool for classifying subjects according to ambiguity attitudes because we conjectured that such attitudes might play some role in responses to our confidence elicitation tasks. We found no evidence to support this, however. Summary statistics of the ambiguity data are reported in Appendix B.

⁹ The random incentive system is a widely used experimental procedure. For a discussion of its rationale and possible limitations see Bardsley, Cubitt, Loomes, Starmer & Sugden (2010).

¹⁰ Before proceeding with the analysis, we dropped the data for four quiz questions that were potentially misleading because the success rate on each of these questions was less than 40% (whereas reported confidence judgements were constrained to the interval 50-100%; see Appendix A). We also excluded data from tables where subjects switched on one row and then switched back again at a later row. Reassuringly, however, less than 2% of the tables of Part 1 and no table in Part 2 included such non-monotonic responses.

4.1. Reproducing Standard Results

Figure 3 provides a quick eye-balling tool for comparing confidence measured using non-incentivized self-reports with confidence elicited using our incentivised mechanism (on the assumption that individuals are risk neutral). Consider first the top left panel. This plots, for each quiz question, the mean of reported confidence against the average success rate. The 45-degree line provides a natural benchmark in the sense that a general tendency to overconfidence would result in points located above the line whereas a general tendency towards underconfidence would result in points below it.¹¹

[Insert Figure 3 around here]

The reported confidence data have a pattern consistent with the familiar ‘hard-easy effect’. To highlight this, we have drawn a vertical (dashed) line through the question which is the median in terms of its success rate (at around 68%). If we define ‘hard’ (‘easy’) questions as those with lower (higher) than median success rates it is then apparent that, on average, there is overconfidence for all but one of the easy questions and underconfidence for all of the hard ones. For each question we measure miscalibration bias as average confidence minus the proportion of correct answers. We then test whether the mean of the distribution of biases is equal to zero using a simple t-test. For easy questions there is significant underconfidence (average bias = -0.115, $p = 0.002$) while for hard questions there is significant overconfidence (average bias = 0.070, $p = 0.001$). Pooling hard and easy questions we cannot reject the null of zero expected bias (average bias = -0.027, $p = 0.312$), evidently because the positive bias on easy questions offsets the negative bias on hard questions.

The top right panel of Figure 3 provides corresponding analysis for confidence inferred from our incentivised elicitation tool, but on the assumption that individuals are *risk neutral*. We refer to this measure as $Conf_{EVi}$ and, from expression 2 above, it is easy to see that this can be calculated directly from an individual’s switchpoint in any given table because $Conf_{EVi} = CE_i/10$. Here, all of the observations sit below the 45-degree line indicating a systematic and highly significant tendency towards underconfidence (average bias = -0.212, $p = 0.000$).

The bottom two panels provide corresponding analysis, but in this case, each dot represents an individual, plotting individual average reported confidence across tasks against the individual’s actual success rate. For the reported confidence treatment individuals with less than

¹¹ Histograms of (average subject level) reported and inferred confidence are also presented in Appendix C.

median success rate are overconfident ($p = 0.085$) and individuals with more than median success rate are underconfident ($p = 0.041$). For the inferred confidence treatment, across all individuals, there is general underconfidence ($p = 0.000$).

Taken together, the results presented in Figure 3 reproduce the standard pattern of findings that motivated our study: Using a procedure based on non-incentivised self-reports of confidence, similar to those used in a range of psychological studies, we reproduce a hard-easy effect; in contrast, using an incentivised procedure to elicit confidence we find a marked tendency towards underconfidence.

4.2. Risk Preferences and Risk-Filtered Confidence

As explained above, if individuals are not risk neutral then confidence measures elicited via our incentivised mechanism will, in part, reflect risk attitudes. This section takes account of this possibility by implementing analysis to filter out the effects of risk attitudes on our incentivised confidence measures.

To this end, we exploit the data from Part 1 of the experiment to fit risk preference models separately for each individual. We do this using one of the leading models of risk preference, rank-dependent utility theory (RDU). We estimate 4 parameters per experimental subject: the utility function and probability weighting parameters under RDU (α , β , γ); and the normalized standard deviations of the decision errors (ν). We omit discussion of the error distribution parameter from the results since they are not central to our analysis.

Figure 4 summarises the results from fitting these models to individuals in our ('Nottingham') study; as a benchmark for our estimates we also report parameters obtained by applying the same econometric method to the data reported in Bruhin, Fehr-Duda & Epper (2010) and Epper, Fehr-Duda & Bruhin (2011) (these are labelled the 'Zurich' estimates). The results for Nottingham and Zurich are qualitatively very similar. The mean of the utility function parameter distribution is close to one and for 75% of Nottingham subjects we cannot reject the null hypothesis that $\alpha = 1$. The means of the parameter estimates for the probability weighting function are also qualitatively similar across Nottingham and Zurich. The graph presented in Figure 4 plots the probability weighting function based on the median estimates of β and γ of the sample and for 45% of subjects we reject the null hypothesis of $\beta = \gamma = 1$. The two plots are qualitatively similar in displaying the inverse-S shape which overweights (underweights) small (large) probabilities; this is quite typical of the broader empirical literature estimating probability weighting functions, at least for data gathered from tasks with stated (as opposed to learned) probabilities (for a review see Starmer 2000; Fehr-Duda, Gennaro & Schubert 2006).

This correspondence between our estimates and those obtained in Zurich provides some reassurance that our procedures for estimating the risk preference measures are reliable (or at least comparably reliable to those based on similar procedures elsewhere in the literature).¹²

[Insert Figure 4 about here]

The significant non-linearity in utility and probability weighting functions for the majority of our subjects strongly suggests that risk attitudes will be a component of confidence measured via $Conf_{EV_i}$. Also notice that from the bottom right panel of Figure 3 it is apparent that $Conf_{EV_i} < 0.5$ for a significant proportion of individuals (47.5%). Given that each task involved a choice between two options, one of which was right, confidence below 50% is implausibly low. In our incentivised task, however, risk aversion (say as measured by concavity of the utility function) would tend to depress $Conf_{EV_i}$. In other words, the data obtained from our incentivised mechanism might seem *more* plausible were we to filter out the effect of departures from risk neutrality.

Using the independent measures of individuals' risk parameters (based on responses to Part 1 of the experiment) we estimate risk-adjusted measures of inferred confidence, based on expression (2) above, as follows:

$$Conf_{RDU_i} = w^{-1} \left(\left(\frac{CE_i}{10} \right)^{\alpha_{RDU}} \right) = \frac{1}{\left(\beta * \left(\frac{CE}{10} \right)^{-\alpha} - \beta \right)^{\frac{1}{\gamma}} + 1} \quad (7)$$

The results of filtering out risk in this way are shown in Figure 5. This plots inferred confidence against actual success rates for each question, with separate panels for the EV and RDU models. For comparison, we also reproduce the reported confidence in the bottom panel. We observe that (i) the extent of underconfidence falls as we move from EV to RDU ($p = 0.025$), (ii) the difference between mean biases of reported and inferred confidence decreases as we filter out risk attitudes ($p = 0.023$), and (iii) inferred confidence is significantly more noisy than reported confidence (Levene (1960) variance equality test: $p = 0.009$). These results suggest that, in the absence of filters for risk attitude, the extent of underconfidence is exaggerated. By filtering out components of these measures attributable to risk attitudes, the overall mean bias falls from -0.212 (inferred confidence under EV) to -0.086 (inferred confidence under RDU).

¹² Histograms of the estimated parameters can be found in Appendix D.

[Insert Figure 5 about here]

While confidence miscalibration is reduced as a consequence of allowing for risk attitudes, it is not eliminated and the mean (underconfidence) bias remains significant for both measures of inferred confidence. Averaging across questions, subjects' success rates are 8.6 percentage points higher than their inferred confidences under our RDU specification. For comparison, success rates are 2.7 percentage points higher than reported confidence. However, as previously noted, the bias in reported confidence varies with difficulty of the question. Thus a better overall measure of miscalibration is the average absolute bias (i.e. the sum of vertical deviations from the 45 degree line). On this measure, inferred RDU confidence (10.2%) and reported confidence (11.6%) are not significantly different ($p = 0.666$).

4.3. Relationship between Reported Confidence and Risk Attitudes

So far we have focussed on the relation between risk attitudes and measured confidence elicited via an incentivised mechanism. Next we explore a possible connection between risk attitudes and self-reported confidence. On the face of it, it seems plausible that confidence might be related to risk attitude. For example, some popular contemporary theories of risk preference can be interpreted as allowing some departures from risk neutrality to arise as consequences of the way that people assess and/or respond to probabilities. For example, prospect theory (Kahneman & Tversky 1979, Tversky & Kahneman 1992) can be interpreted as allowing for both misperception of objective probabilities and subjective attitudes to whatever probabilities are perceived. To the extent that such processes reflect generic properties of the way that humans perceive and respond to risks, that provides reason to expect that similar processes might operate in relation to confidence judgements because those judgments *are* assessments of probabilities. We investigate this possibility by examining the correlation between individual level risk parameters and reported confidence. Notice that, whereas we have reason to believe that *Conf_{EV}* and *Conf_{RDU}* may be correlated with risk attitudes because of an influence introduced via the measurement technique, in the case of reported confidence, there is no such transmission mechanism. As such, a correlation between risk attitudes and reported confidence would be suggestive of an intrinsic link between confidence and risk attitudes.

[Insert Table 2 about here]

Table 2 presents the results of OLS regressions where the dependent variable is average reported confidence (subject level). The table reports two model specifications. Model 1 uses estimated RDU parameters as regressors, and Model 2 includes additional controls for average success rates, demographic variables and the measure of ambiguity aversion elicited from the questionnaire. Since some of the regressors are estimated, we use bootstrapped standard errors to account for measurement error in the independent variables.

For both models, there is no significant association between average reported confidence levels and average success rates across subjects.¹³ None of the other control variables have any significant predictive power for confidence levels. Turning to the risk parameter estimates, curvature of the utility function is positively related to reported confidence levels in both specifications, with greater risk seeking (as captured by higher α) associated with higher confidence. We do not find a robust significant effect of the probability weighting elevation parameter β .¹⁴ The significant positive effect of γ in both specifications has a natural interpretation. Recall that γ controls curvature of the weighting function, then notice that, for our tasks, success rates are such that we are typically operating in a region where the median subject's weighting function underweights probabilities. In this region, increases in γ reduce underweighting. Hence, the positive sign here is consistent with a positive association between underweighting and underconfidence.¹⁵ We believe the analysis in this section is novel, and scientifically interesting, suggesting the possibility of common psychological mechanisms underpinning risk attitudes and confidence judgements.

5. Discussion

There is a very large empirical literature investigating confidence judgements and much of this points to the presence of overconfidence in a range of judgements or the existence of a hard-easy

¹³ We also checked the relation between confidence and success in a more disaggregate analysis using responses to each question (rather than averages) as the dependent variable. In this analysis, there is a positive and significant association between success and expressed confidence levels; confidence is about 8.5% higher when a subject's answer to a question is correct. This relationship fades away in average subject-level analysis which is consistent with the findings by e.g. Kruger & Dunning (1999) and Massoni & Roux (2012).

¹⁴ In Table 2 we report our most parsimonious model, using just the risk attitude variables, and our most general model. We also examined intermediate cases excluding some of the questionnaire variables. We found that the significant effects captured by α and γ are robust across model specifications, but the effect captured by β is sensitive to model specification. For example, if the gender dummy is excluded from Model 2, β becomes significantly positive at the 5% level.

¹⁵ We also examined the relationship between reported confidence and another simple proxy for risk attitudes represented as the individual's average switch point (ASP) in Part 1 of the experiment. This revealed significant positive association between ASP and reported confidence consistent with higher confidence for less risk averse individuals. Notice that this ASP measure of risk attitude does not rely on any particular model of risk preference. Results of this analysis is reported in Table E1 of Appendix E.

effect. The bulk of this literature, however, rests on data generated from non-incentivised self-reports of confidence and, more recently, the robustness of conclusions from this line of research has been challenged by studies from experimental economists which use incentivised tasks to elicit confidence judgements and find that overconfidence is considerably reduced. Indeed, in these recent studies, underconfidence is the typical finding.

Our study contributes to this literature, and its central novelty lies in combining two key design features. First, we compare confidence miscalibration across incentivised and non-incentivised confidence elicitation tasks. Second, we build into our design procedures for measuring the risk attitudes of our participants coupled with techniques that allow us to track how filtering out risk attitudes affects the measurement of confidence via the incentivised procedure. With the data generated from our design, we are also able to investigate a possible link between reported confidence and risk attitudes at the individual level.

Using a non-incentivised procedure, designed to be very similar to those used in much of the background psychology literature, we reproduce the standard finding of a hard-easy effect. With our new incentivised confidence measurement, regardless of whether or not we filter for risk attitudes, and in line with the recent experimental economics literature, we observe a general tendency towards underconfidence and the hard-easy effect disappears.

Our primary novel findings then relate to the impacts of risk aversion on measured confidence. In the context of incentivised confidence elicitation, we find that filtering out risk attitudes from inferred confidence reduces the degree of underconfidence. We also observe a striking association between risk attitudes inferred from incentivised decisions about lotteries and confidence measured using the unincentivized tool. Specifically, individuals who are more risk averse tend to express lower confidence.

As far as we know, we are the first to provide direct evidence that risk attitudes play a significant role in determining confidence judgements. While we have argued that some such connection is intuitively plausible, the fact that the association appears to work through *both* attitudes to consequences and attitudes to chance is striking: in our data underconfidence is associated with *both* more concave utility over consequences and more extreme underweighting of probabilities. In our view the discovery of an association between probability weighting and confidence is particularly intriguing. To those who tend to think of probability weighting as reflecting more general underlying principles of cognition, the manifestation of those principles in another domain will be reassuring, but not, perhaps especially surprising. We suspect, however, that many economists previously aware of evidence of probability weighting may, quite reasonably, think of it as an essentially empirical regularity derived, mainly, from

observing choices among simple gambles, with stated probabilities. To those who do interpret it in this, more limited, way our results are arguably much more surprising by establishing a clear empirical connection between responses to probabilities in two very different domains: one involving attachment of certainty equivalents to gambles with stated probabilities (Part 1 of our experiment); the other involving self-reported probability judgements about one's own success rate in a given question (Part 2 of our experiment). We suggest that the ability of measured (non-linear) probability weighting to predict behaviour in these very different tasks and domains is a positive signal of the explanatory scope and significance of the concept of probability weighting within economics.

Given that probability weighting does appear to influence confidence judgements, it is natural to ask whether other 'non-standard' aspects of preference in relation to risk or uncertainty might affect confidence judgements. In this respect, an obvious candidate to consider is ambiguity aversion, particularly since confidence judgments appear to be intrinsically ambiguous (as opposed to risky). Although this raises issues beyond the boundaries of the present study, our end of study questionnaire did include a task intended to measure attitudes to ambiguity. Using these data we found that subjects identified as ambiguity averse did not switch differently in the confidence elicitation tables compared to ambiguity neutral subjects. Nor did we find any relationship between ambiguity attitudes and self-reported confidence. This is, of course, far from conclusive evidence that there is no relationship to discover, and there is certainly scope for further research into this issue and the broader question - previously highlighted by Hoelzl & Rustichini (2005), Offerman et al. (2009) and Kothiyal, Spinu & Wakker (2011) - of how to assess and control the potential impact of ambiguity attitudes in the context of incentivised belief elicitation.

We conclude with a brief cautionary remark. Whether or not people's confidence judgements are well calibrated is clearly an important issue in a range of economically relevant field contexts (Harrison & Phillips, 2014). As such, economists have, understandably, shown an interest in the large volume of evidence supporting overconfidence in the lab and field. While it seems entirely appropriate to analyse the consequences of confidence miscalibration, it now looks naïve to proceed, as some have done in the past, by simply assuming overconfidence as a reasonable empirical assumption (Odean 1999; Compte & Postlewaite 2004; Malmendier & Tate 2005; Galasso & Simcoe 2011; Gervais, Heaton & Odean 2011). In contrast, our results, alongside other recent work (e.g., Hoelzl & Rustichini 2005; Moore & Healy 2008; Blavatskyy 2009; Clark & Friesen 2009; Merkle & Weber 2011), support the following conclusion: while miscalibration of confidence judgements occurs and persists in controlled incentivised decisions,

there is currently – and perhaps ironically – apparent overconfidence regarding the empirical significance of overconfidence. We hope that our work provides a helpful input to recalibration.

References

- Abdellaoui, M., L'haridon, O., & Paraschiv, C. (2011). “Experienced vs. Described Uncertainty: Do We Need Two Prospect Theory Specifications?” *Management Science*, Vol. 57, pp.1879-1895.
- Alba J. W. & Hutchinson J. W. (2000). “Knowledge Calibration: What Consumers Know and What They Think They Know”, *Journal of Consumer Research*, Vol. 27, pp. 123-156.
- Andersen, S., Harrison, G. W., Lau, M. I. & Rutstrom, E. E. (2006). “Elicitation Using Multiple Price List Formats”, *Experimental Economics*, Vol. 9, pp. 383-405.
- Andersson, P., Edman, J., & Ekman, M. (2005). “Predicting the World Cup 2002 in Soccer: Performance and Confidence of Experts and non-Experts.” *International Journal of Forecasting*, Vol. 21, pp. 565-576.
- Aukutsionek, S. P., & Belianin, A. V. (2001). “Quality of Forecasts and Business Performance: A Survey Study of Russian Managers.” *Journal of Economic Psychology*, Vol. 22, pp. 661-692.
- Bardsley, N., Cubitt, R., Loomes, G., Moffat, P., Starmer, C. & Sugden, R. (2010). “Experimental Economics: Rethinking the Rules”. Princeton University Press.
- Becker, A., Deckers, T., Dohmen, T., Falk, A., & Kosse, F. (2012). “The Relationship Between Economic Preferences and Psychological Personality Measures”, IZA Discussion Paper Series No. 6470.
- Biais, B., Hilton, D., Mazurier, K. & Pouget, S. (2005). “Judgemental Overconfidence, Self-Monitoring, and Trading Performance in an Experimental Financial Market”, *Review of Economic Studies*, Vol. 72, pp. 287-312.
- Blavatsky, P. (2009). “Betting on Own Knowledge: Experimental Test of Overconfidence”, *Journal of Risk and Uncertainty*, Vol. 38, pp. 39-49.
- Braun, P. A., & Yaniv, I. (1992). “A Case Study of Expert Judgment: Economists' Probabilities versus Base Rate Model Forecasts.” *Journal of Behavioral Decision Making*, Vol. 5, pp. 217-231.
- Bruhin, A., Fehr-Duda, H. & Epper, T. (2010). “Risk and Rationality: Uncovering Heterogeneity in Probability Distortion”, *Econometrica*, Vol. 78, No.4, pp.1375-1412.
- Camerer, C. & Lovallo, D. (1999). “Overconfidence and Excess Entry: An Experimental Approach”, *The American Economic Review*, Vol. 89, pp. 306-318.

- Campbell, W. K., Goodie, A. S. & Foster, J. D. (2004). "Narcissism, Confidence, and Risk Attitude", *Journal of Behavioural Decision Making*, Vol. 17, pp. 297-311.
- Clark, J. & Friesen, L. (2009). "Overconfidence in Forecasts of own Performance: an Experimental Study", *The Economic Journal*, Vol.119, pp. 229 - 251.
- Cohen, M., Jaffray, J. Y., & Said, T. (1987). "Experimental Comparison of Individual Behavior under Risk and under Uncertainty for Gains and for Losses." *Organizational Behavior and Human Decision Processes*, Vol. 39, pp. 1-22.
- Compte, O. & Postlewaite, A. (2004). "Confidence-Enhanced Performance", *The American Economic Review*, Vol. 94, pp. 1536-1557.
- Dickinson, D.L. (2006). "The Chilling Effect of Optimism: the Case of Final-offer Arbitration", *Journal of Socio-Economics*, Vol. 35, pp. 17–30.
- Dubra, J. (2004). "Optimism and Overconfidence in Search", *Review of Economic Dynamics*, Vol. 7, pp. 198-218.
- Dunning, D., Heath, C. & Suls, J. M. (2004). "Flawed Self-Assessment: Implications for Health, Education, and the Workplace", *Psychological Science in the Public Interest*, Vol. 5, pp. 69–106.
- Ellsberg, D. (2001). *Risk, Ambiguity, and Decision*. Taylor & Francis.
- Epper, T., Fehr-Duda, H. & Bruhin, A. (2011). "Viewing the Future through a Warped Lens: Why Uncertainty Generates Hyperbolic Discounting", *Journal of Risk and Uncertainty*, Vol. 43, pp. 169-203.
- Fehr-Duda, H., Bruhin, A., Epper, T. & Schubert, R. (2010). "Rationality on the Rise: Why Relative Risk Aversion Increases with Stake Size", *Journal of Risk and Uncertainty*, Vol. 40, pp. 147-180.
- Fehr-Duda, H., de Gennaro, M. & Schubert, R. (2006). "Gender, Financial Risk and Probability Weights", *Theory and Decision*, Vol. 60, pp. 283-313.
- Fischhoff, B., Slovic, P. & Lichtenstein, S. (1977). "Knowing with Certainty: The Appropriateness of Extreme Confidence", *Journal of Experimental Psychology: Human Perception and Performance*, Vol. 3, pp. 552-564.
- Galasso, A. & Simcoe, T. S. (2011). "CEO Overconfidence and Innovation", *Management Science*, Vol. 57, pp. 1469-1484.
- Gervais, S., Heaton, J.B. & Odean, T. (2011). "Overconfidence, Compensation Contracts and Capital Budgeting", *The Journal of Finance*, Vol. 66, pp. 1735-1777.
- Gigerenzer, G., Hoffrage, U. & Kleinbolting, H. (1991). "Probabilistic Mental Models: A Brunswikian Theory of Confidence", *Psychological Review*, Vol. 98, pp. 506-528.

- Goldstein, W.M. & Einhorn, H.J. (1987). “Expression Theory and the Preference Reversal Phenomena”, *Psychological Review*, Vol. 94, pp. 236-254.
- Greiner, B. (2004). An Online Recruitment System for Economic Experiments. In: Kurt Kremer, Volker Macho (Eds.): Göttingen :Ges. fürsWiss. Datenverarbeitung, pp. 79-93.
- Griffin, D. & Brenner, L. (2008). “Perspectives on Probability Judgment Calibration”, in Blackwell Handbook of Judgment and Decision Making (eds D. J. Koehler and N. Harvey), Blackwell Publishing Ltd, Malden, MA, USA, pp.177-199.
- Harrison, G. W., Martínez-Correa, J., Swarthout, J. T., & Ulm, E. R. (2013). “Scoring rules for Subjective Probability Distributions” (No. 2013-05). Experimental Economics Center, Andrew Young School of Policy Studies, Georgia State University.
- Harrison, G. W., & Phillips, R. D. (2014). “Subjective Beliefs and Statistical Forecasts of Financial Risks: The Chief Risk Officer Project”. Working Paper 2014.
- Herz, H., Schunk, D. & Zehnder, C. (2014). “How Do Judgmental Overconfidence and Overoptimism Shape Innovative Activity?” *Games and Economic Behavior*, Vol. 83, pp. 1-23.
- Hoelzl, E. & Rustichini, A. (2005). “Overconfident: Do You Put Your Money on It?” *The Economic Journal*, Vol. 115, pp. 305-318.
- Hollard G., Massoni S. & Vergnaud J.C. (2010). “Subjective Beliefs Formation and Elicitation Rules: Experimental Evidence”, Working Paper, CES Paris.
- Isoni, A., Loomes, G. & Sugden, R. (2011). “The Willingness to Pay—Willingness to Accept Gap, the “Endowment Effect,” Subject Misconceptions, and Experimental Procedures for Eliciting Valuations: Comment”, *The American Economics Review*, Vol. 101, pp. 991-1011.
- Kahneman, D. & Tversky, A. (1979). “Prospect Theory: An Analysis of Decision under Risk”, *Econometrica*, Vol. 47, pp. 263–91.
- Keren, G. (1991). “Calibration and Probability Judgements: Conceptual and Methodological Issues”, *ActaPsychologica*, Vol. 77, pp. 217-273.
- Kothiyal, A., Spinu, V., & Wakker P.P. (2011). “Comonotonic Proper Scoring Rules to Measure Ambiguity and Subjective Beliefs”, *Journal of Multi-Criteria Decision Analysis*, Vol. 17, pp. 101-113.
- Kruger, J. & Dunning, D. (1999). “Unskilled and Unaware of It: How Difficulties in Recognizing One’s Own Incompetence Lead to Inflated Self-Assessments”, *Journal of Personality and Social Psychology*, Vol. 77, pp. 1121-1134.

- Lattimore, P. K., Baker, J. R., & Witte, A. D. (1992). "The Influence of Probability on Risky Choice: A Parametric Examination". *Journal of Economic Behavior & Organization*, Vol. 17, pp. 377-400.
- Levene, H. (1960). "Robust Tests for Equality of Variances", in *Contributions to Probability and Statistics: Essays in Honor of Harold Hotelling*, ed. I. Olkin, S. G. Ghurye, W. Hoeffding, W. G. Madow, and H. B. Mann, 278-292. Menlo Park, CA: Stanford University Press.
- Liberman, V. (2004). "Commentary: Local and Global Judgements of Confidence", *Journal of Experimental Psychology: Learning, Memory and Cognition*, Vol. 30, pp. 729-732.
- Lichtenstein, S. & B. Fischhoff (1981). "The Effects of Gender and Instructions on Calibration", Decision Research Technical Report 81-5, Decision Research, Eugene, OR.
- Lichtenstein, S., B. Fischhoff & L. D. Phillips (1982). "Calibration of Probabilities: The State of the Art to 1980", in D. Kahneman, P. Slovic and A. Tversky (eds), *Judgment Under Uncertainty: Heuristics and Biases*, Cambridge Press. Cambridge. MA. pp. 306-334.
- Lundeberg, M. A., Fox, P. W., Brown, A. C. & Elbedour, S. (2000). "Cultural Influences in Confidence: Country and Gender", *Journal of Educational Psychology*, Vol. 92, pp. 152-159.
- Malmendier, U. & Tate, G. (2005). "CEO Overconfidence and Corporate Investment", *Journal of Finance*, Vol. 60, pp. 2661-2700.
- Massoni, S. & Roux, N. (2012). "Optimal Group Decision: A Matter of Confidence Calibration", Working Paper, CES Paris.
- Merkle, C. & Weber, M. (2011). "True Overconfidence: The Inability of Rational Information Processing to Account for Apparent Overconfidence", *Organizational Behaviour and Human Decision Processes*, Vol. 116, pp. 262-271.
- Moore, D. A. & Cain, D. M. (2007). "Overconfidence and Underconfidence: When and Why People Underestimate (and Overestimate) the Competition", *Organizational Behaviour and Human Decision Processes*, Vol. 103, pp. 197-213.
- Moore, D. & Healy P. J. (2008). "The Trouble with Overconfidence", *Psychological Review*, Vol. 115, pp. 502-517.
- Murphy, A. H., & Daan, H. (1984). "Impacts of Feedback and Experience on the Quality of Subjective Probability Forecasts. Comparison of Results from the First and Second Years of the Zierikzee Experiment". *Monthly Weather Review*, Vol. 112, pp. 413-423.
- Niederle, M. & Vesterlund, L. (2007). "Do Women Shy Away from Competition? Do Men Compete too Much?" *Quarterly Journal of Economics*, Vol. 122, pp. 1067-1101.

- Odean, T. (1999). "Do Investors Trade Too Much?" *The American Economic Review*, Vol. 89, pp. 1279-1298.
- Offerman, T., Sonnemans, J., van de Kuilen, G. & Wakker, P. (2009). "A Truth Serum for Non-Bayesians: Correcting Proper Scoring Rules for Risk Attitudes", *Review of Economic Studies*, Vol. 76, pp. 1461-1489.
- Olsson, H. (2014). "Measuring Overconfidence: Methodological Problems and Statistical Artifacts." *Journal of Business Research*, Vol. 67, pp. 1766-1770.
- Rustichini, A., De Young, C. G., Anderson, J. & Burks, S. V. (2012). "Towards the Integration of Personality Theory in the Explanation of Economic and Health Behavior", IZA Discussion Paper Series No. 6750.
- Schaefer, P. S., Williams, C. C., Goodie, A. S. & Campbell, W. K. (2004). "Overconfidence and the Big Five", *Journal of Research in Personality*, Vol. 38, pp. 473-480.
- Starmer, C. (2000). "Developments in Non-Expected Utility Theory: The Hunt for a Descriptive Theory of Choice under Risk", *Journal of Economic Literature*, Vol. 38, pp. 332-382.
- Suantak, L., Bolger, F. & Ferrel, W.R. (1996). "The Hard-Easy Effect in Subjective Probability Calibration", *Organizational Behaviour and Human Decision Processes*, Vol. 67, pp. 201-221.
- Svenson, O. (1981). "Are We All Less Risky and More Skilful than Our Fellow Drivers?" *Acta Psychologica*, Vol. 47, pp. 143-148.
- Trautmann, S. T., & van de Kuilen, G. (2014). "Belief Elicitation: A Horse Race among Truth Serums". *The Economic Journal*, forthcoming.
- Tversky, A. & Kahneman, D. (1992). "Advances in Prospect Theory: Cumulative Representation of Uncertainty", *Journal of Risk Uncertainty*, Vol. 5, pp. 297-323.
- Urbig, D., Stauf, J. & Weitzel, U. (2009). "What is Your Level of Overconfidence? A Strictly Incentive Compatible Measurement of Absolute and Relative Overconfidence", Discussion Paper Series 09-20, Utrecht School of Economics.
- Wakker, P. P. (2010). "Prospect Theory: For Risk and Ambiguity", Cambridge University Press, Cambridge, UK.
- Wu, G., Zhang, J., & Gonzalez, R. (2004). "Decision under Risk", in *The Blackwell Handbook of Judgment and Decision Making*, ed. by D. Koehler and N. Harvey. Oxford: Oxford University Press, 399-423.

Figures

<p>Which of the following cities has the larger population? <input type="checkbox"/> City X <input type="checkbox"/> City Y Tick one of the boxes to indicate your answer.</p> <p>In each row of the table choose either Option A or B.</p>				
Row	Option A: Lottery	Your Choice		Option B: Guaranteed Amount
		A	B	
1		<input type="checkbox"/>	<input type="checkbox"/>	£10.00
2		<input type="checkbox"/>	<input type="checkbox"/>	£9.50
3		<input type="checkbox"/>	<input type="checkbox"/>	£9.00
4		<input type="checkbox"/>	<input type="checkbox"/>	£8.50
5		<input type="checkbox"/>	<input type="checkbox"/>	£8.00
6		<input type="checkbox"/>	<input type="checkbox"/>	£7.50
7		<input type="checkbox"/>	<input type="checkbox"/>	£7.00
8		<input type="checkbox"/>	<input type="checkbox"/>	£6.50
9	You get £10.00 if your city choice is correct and £0.00 if not	<input type="checkbox"/>	<input type="checkbox"/>	£6.00
10		<input type="checkbox"/>	<input type="checkbox"/>	£5.50
11		<input type="checkbox"/>	<input type="checkbox"/>	£5.00
12		<input type="checkbox"/>	<input type="checkbox"/>	£4.50
13		<input type="checkbox"/>	<input type="checkbox"/>	£4.00
14		<input type="checkbox"/>	<input type="checkbox"/>	£3.50
15		<input type="checkbox"/>	<input type="checkbox"/>	£3.00
16		<input type="checkbox"/>	<input type="checkbox"/>	£2.50
17		<input type="checkbox"/>	<input type="checkbox"/>	£2.00
18		<input type="checkbox"/>	<input type="checkbox"/>	£1.50
19		<input type="checkbox"/>	<input type="checkbox"/>	£1.00
20		<input type="checkbox"/>	<input type="checkbox"/>	£0.50

Figure 1: Our Confidence Elicitation Tool

For each row of the table please choose either Option A or B				
Row	Option A: Lottery	Your Choice		Option B: Guaranteed amount of
		A	B	
1	50% chance of £10.00 and 50% chance of £0.00	<input type="checkbox"/>	<input type="checkbox"/>	£10.00
2		<input type="checkbox"/>	<input type="checkbox"/>	£9.50
3		<input type="checkbox"/>	<input type="checkbox"/>	£9.00
4		<input type="checkbox"/>	<input type="checkbox"/>	£8.50
5		<input type="checkbox"/>	<input type="checkbox"/>	£8.00
6		<input type="checkbox"/>	<input type="checkbox"/>	£7.50
7		<input type="checkbox"/>	<input type="checkbox"/>	£7.00
8		<input type="checkbox"/>	<input type="checkbox"/>	£6.50
9		<input type="checkbox"/>	<input type="checkbox"/>	£6.00
10		<input type="checkbox"/>	<input type="checkbox"/>	£5.50
11		<input type="checkbox"/>	<input type="checkbox"/>	£5.00
12		<input type="checkbox"/>	<input type="checkbox"/>	£4.50
13		<input type="checkbox"/>	<input type="checkbox"/>	£4.00
14		<input type="checkbox"/>	<input type="checkbox"/>	£3.50
15		<input type="checkbox"/>	<input type="checkbox"/>	£3.00
16		<input type="checkbox"/>	<input type="checkbox"/>	£2.50
17		<input type="checkbox"/>	<input type="checkbox"/>	£2.00
18		<input type="checkbox"/>	<input type="checkbox"/>	£1.50
19		<input type="checkbox"/>	<input type="checkbox"/>	£1.00
20		<input type="checkbox"/>	<input type="checkbox"/>	£0.50

Figure 2: Sample Risk Elicitation Tool

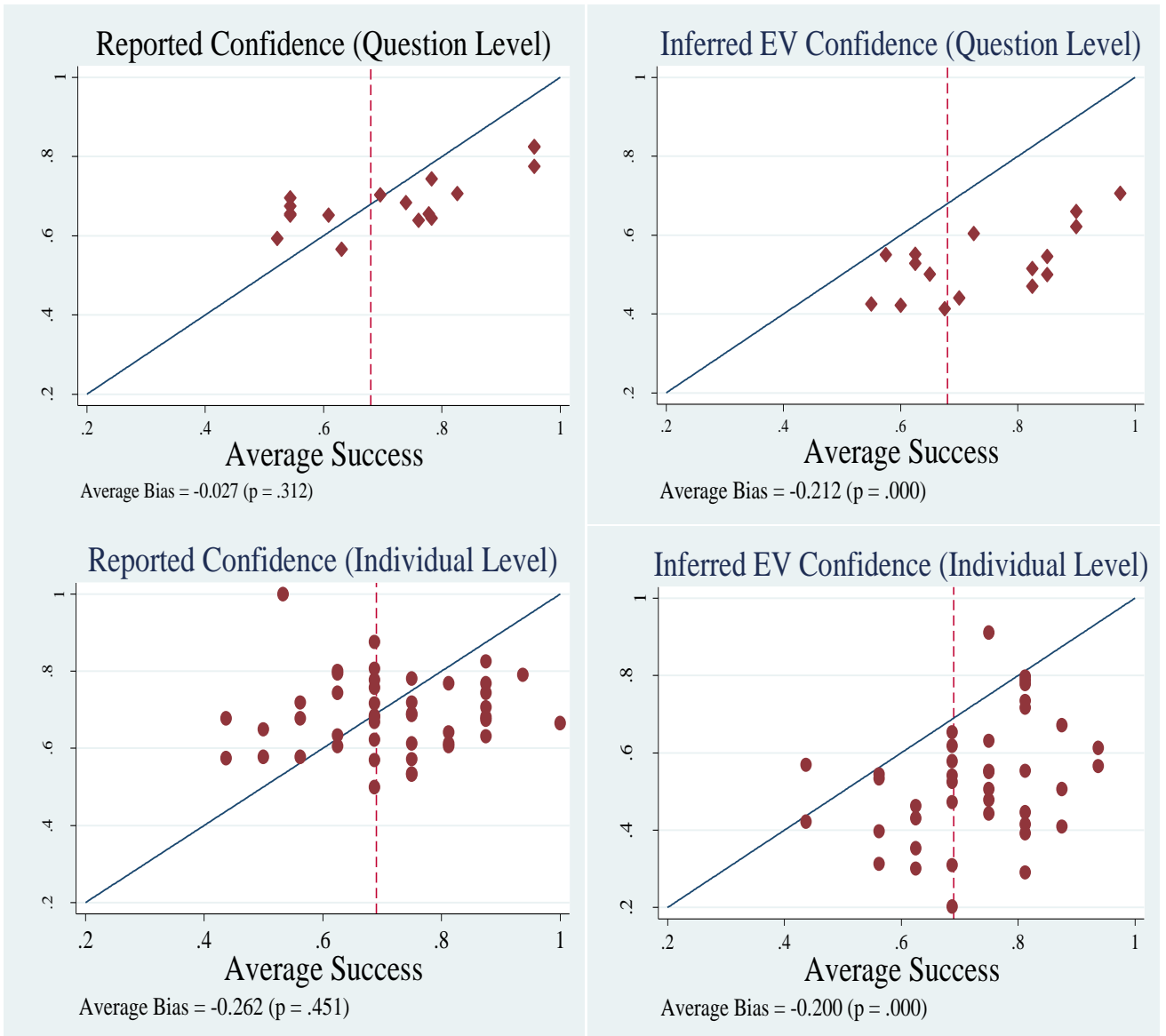


Figure 3: Confidence and Success

Top panels: Each dot represents a question. For a given question, $\text{Bias} = (\text{average confidence}) - (\text{average success})$ across subjects. Average bias is the mean across questions and the reported p-value is for a two-tailed t-test that mean of the distribution of biases is zero. Bottom panels: Each dot represents a subject. For a given subject, $\text{bias} = (\text{average confidence across questions}) - (\text{success rate across questions})$. Average bias is the mean across subjects and the reported p-value is for a two-tailed t-test that the mean of the distribution of biases is zero.

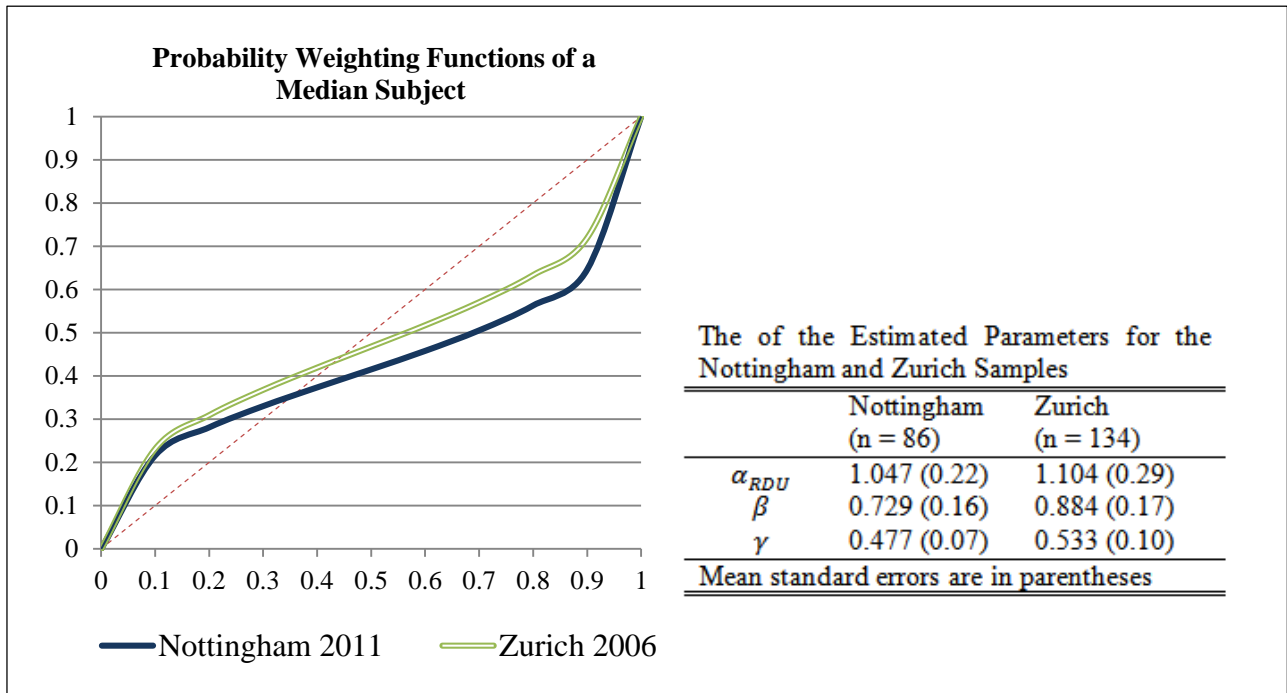
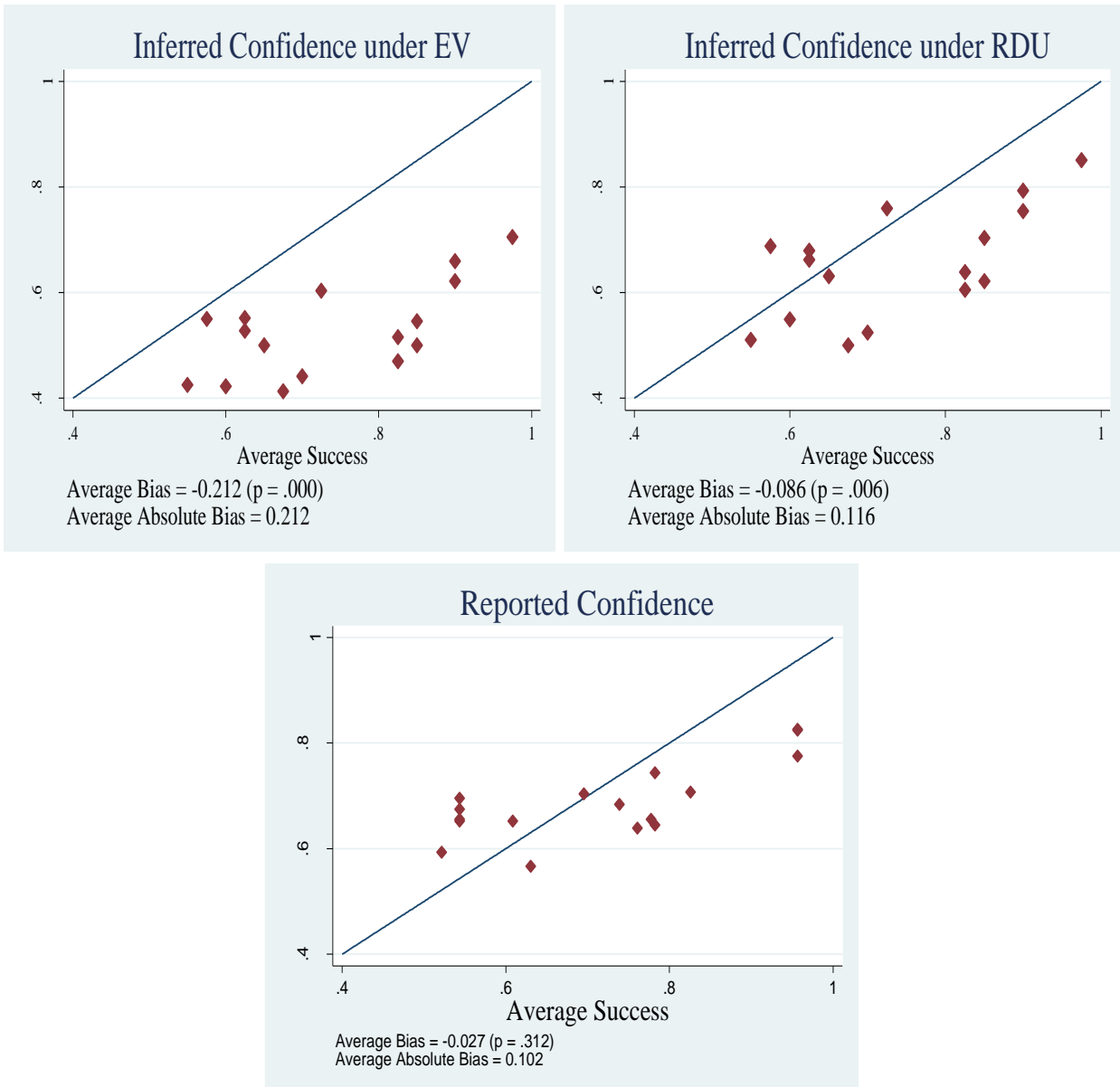


Figure 4: Estimates of risk preference parameters: the plot is the weighting function based on the median estimates of β and γ of the sample



Each dot represents a question. For a given question, Bias = (Average Confidence – Average Success) across subjects. Average bias is the mean across all questions and the reported p-value is for a two-tailed t-test that mean of distribution of biases is zero. Absolute Bias = Absolute (Average Confidence– Average Success) across subjects.

Figure 1: Risk Adjusted Confidence and Success

Tables

Table 1: Risky Prospects of Part 1 of the experiment

Lottery	p	x_1	x_2	Lottery	p	x_1	x_2
1	0.05	£4	£0	14	0.5	£10	£0
2	0.05	£8	£2	15	0.5	£10	£4
3	0.05	£10	£4	16	0.5	£30	£0
4	0.05	£30	£10	17	0.75	£4	£0
5	0.1	£2	£0	18	0.75	£8	£2
6	0.1	£4	£2	19	0.75	£10	£4
7	0.1	£10	£0	20	0.9	£2	£0
8	0.25	£4	£0	21	0.9	£4	£2
9	0.25	£8	£2	22	0.9	£10	0
10	0.25	£10	£4	23	0.95	£4	£0
11	0.5	£2	£0	24	0.95	£8	£2
12	0.5	£4	£2	25	0.95	£10	£4
13	0.5	£8	£2				

p denotes the probability of the first outcome, x_1

Table 2: Dependant Variable Average Reported Confidence

<i>Explanatory Variables</i>	<i>Model 1</i>	<i>Model 2</i>
α	.125*** (0.05)	.124** (0.055)
β	.078 (0.05)	.097 (0.060)
γ	.096** (0.051)	.109** (0.054)
Average Success		.029 (0.112)
Female		-.037 (0.028)
Age		-.013 (0.009)
Ambig. Averse		-.013 (0.032)
Constant	.453*** (.078)	.704*** (.202)
\bar{R}^2	.203	.251
n	45	43

* 10%, ** 5%, *** 1% significance levels

Standard errors (in parentheses) are obtained by the bootstrap method with 1,000 replications. Bootstrapping accounts for the fact that the regressors α , β and γ are estimated quantities.

Appendix A: City quiz questions

[The percentages of correctly given answers are in parenthesis.]

Which of the following two cities has the larger population? (59.6%)

- Athens, Greece Amsterdam, Netherlands

Which of the following two cities has the larger population? (23.2%)

- Philadelphia, USA Havana, Cuba

Which of the following two cities has the larger population? (63.5%)

- Los Angeles, USA Kolkata, India

Which of the following two cities has the larger population? (38.1%)

- Rome, Italy Lima, Peru

Which of the following two cities has the larger population? (59.7%)

- Cairo, Egypt Brasilia, Brazil

Which of the following two cities has the larger population? (57.9%)

- Tehran, Iran Seattle, USA

Which of the following two cities has the larger population? (74.1%)

- Warsaw, Poland Nairobi, Kenya

Which of the following two cities has the larger population? (57.2%)

- San Diego, California, USA Dallas, Texas, USA

Which of the following two cities has the larger population? (83.8%)

- Buenos Aires, Argentina Rio De Janeiro, Brazil

Which of the following two cities has the larger population? (45.9%)

- Seoul, South Korea Singapore, Singapore

Which of the following two cities has the larger population? (96.5%)

- Cairo, Egypt Shanghai, China

Which of the following two cities has the larger population? (58.4%)

Istanbul, Turkey

Sydney, Australia

Which of the following two cities has the larger population? (81.3%)

Lima, Peru

Sao Paolo, Brazil

Which of the following two cities has the larger population? (92.8%)

Dubai, United Arab Emirates

Tokyo, Japan

Which of the following two cities has the larger population? (92.8%)

Mumbai, India

Berlin, Germany

Which of the following two cities has the larger population? (75.4%)

Paris, France

Mexico City, Mexico

Which of the following two cities has the larger population? (46.1%)

Budapest, Hungary

Caracas, Venezuela

Which of the following two cities has the larger population? (78.2%)

Milan, Italy

Malaga, Spain

Which of the following two cities has the larger population? (69.2%)

Coventry, UK

Leicester, UK

Which of the following two cities has the larger population? (65.3%)

Oslo, Norway

Stockholm, Sweden

Appendix B: Post Study Questionnaire

1) What is your sex? Male Female

2) What is your age? _____

3) [Ellsberg's Urn Problem:]

Suppose that you are shown a bag which contains 90 balls. Of these, 30 are red. The remaining 60 balls are some mixture of black and yellow, but you do not know what the mixture is. One ball is to be drawn at random from the bag. You are asked to choose one of two options: Option I will give you £10 if a red ball is drawn, while Option II will give you £10 if a black ball is drawn. This choice may be written as follows:

	Red	Black	Yellow
<input type="checkbox"/> Option I	£10	£0	£0
<input type="checkbox"/> Option II	£0	£10	£0

Which would you choose? Please tick the corresponding box.

Now suppose, instead, that you are offered a different choice of options, defined in terms of the same draw of a ball from the same bag. You must choose one of Options III and IV:

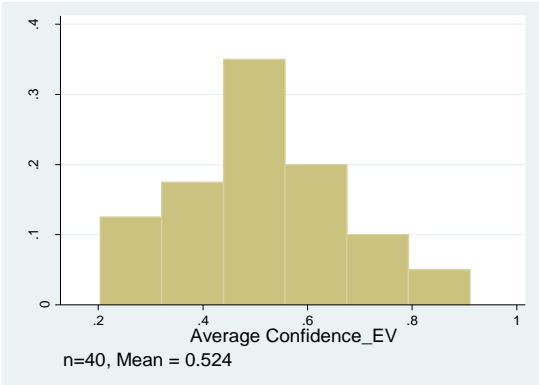
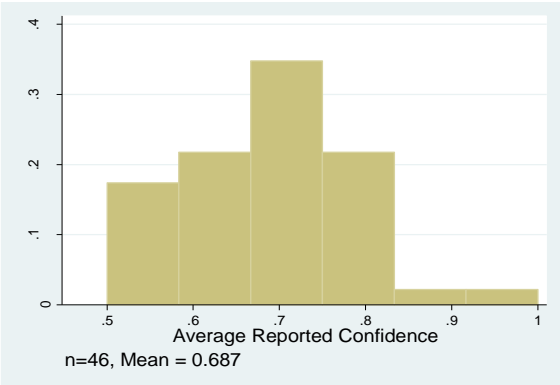
	Red	Black	Yellow
<input type="checkbox"/> Option III	£10	£0	£10
<input type="checkbox"/> Option IV	£0	£10	£10

Which would you choose now? Please tick the corresponding box.

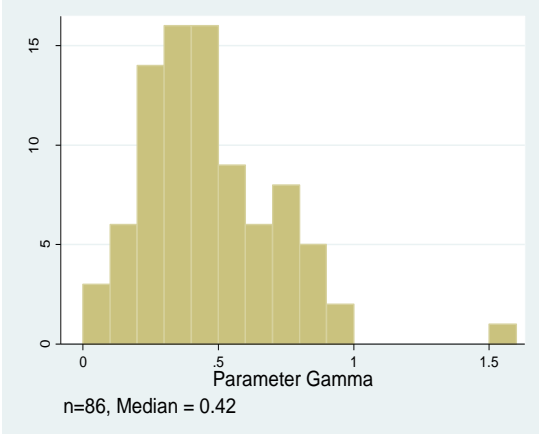
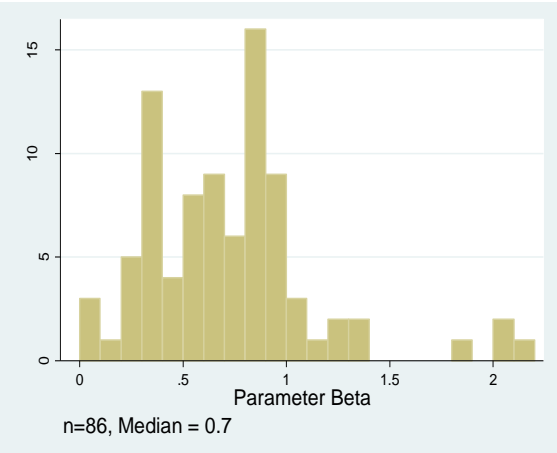
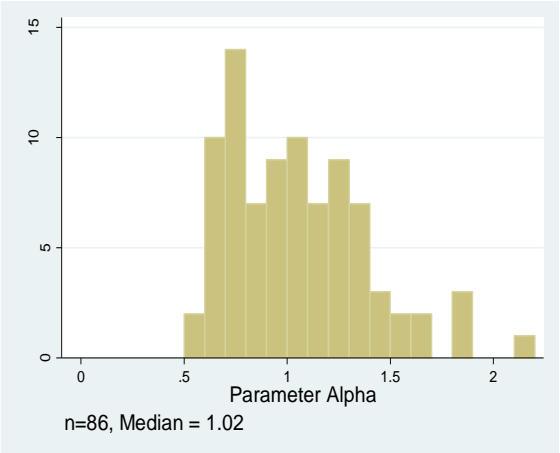
Table B1: Summary Statistic of Descriptive Variables, n=86		Scale	Mean	Std Error
Female	Binary	0 or 1	0.44	0.50
Age	Numeric	Continuous	20.2	2.17
Ambig	Qualitative	Ambig averse, seeking, or neutral	Averse: 55 Seeking: 1 Neutral 30	

Ambiguity attitudes were calculated by classifying subjects as ambiguity averse if Option I and IV was chosen, ambiguity seeking if Option II and III was chosen and ambiguity neutral if Option I and III or Options II and IV was chosen.

Appendix C: Histogram of Average Reported Confidence and $Conf_{EV}$



Appendix D: Histogram of Risk Parameters



Appendix E: Average Switch Point as an alternative Risk Measure

Table E1: Dependant Variable Average Reported Confidence

<i>Explanatory Variables</i>	<i>Model 1</i>	<i>Model 2</i>
Average Switch Point	0.054** (0.024)	0.089*** (0.028)
Average Success		0.032 (0.105)
Female		-0.037 (0.029)
Age		-0.024*** (0.008)
Ambig Averse		-0.014 (0.033)
Constant	0.457*** (0.102)	0.819*** (0.164)
\bar{R}^2	0.087	0.224
n	44	41

* 10%, ** 5%, *** 1% significance levels

Average switch point is a simple proxy for risk attitudes represented as the individual's average switch point in Part 1 of the experiment. Standard errors (in parentheses).