Risk and Ambiguity in Evaluating Entrepreneurial Prospects: An Experimental Study

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Abstract

Past research points to risk attitudes as an important variable driving decisions to enter entrepreneurship. However, entrepreneurs confront more often uncertainty and ambiguity, or unknown probabilities, rather than risk, or known probabilities concerning the success of a venture. Through an online experiment we investigate risk and ambiguity attitudes of entrepreneurs and non-entrepreneurs in occupational choice decisions, for different likelihood levels and different degrees of ambiguity. Findings suggest that both entrepreneurs and non-entrepreneurs seek risk and ambiguity for low likelihoods and avoid risk and ambiguity for high likelihoods, a behavioral pattern consistent with Prospect Theory. We observe that entrepreneurs exhibit more optimism for both risk and ambiguity compared to non-entrepreneurs, across likelihood levels and degrees of ambiguity. However, entrepreneurs give more pessimistic evaluations for ambiguity compared to risk; non-entrepreneurs do not discriminate between risk and ambiguity, exhibiting the same pattern of behavior in both conditions.

Keywords risk attitudes · ambiguity attitudes · entrepreneurship · experiment

JEL classification D81 · L26 · C93

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1 Introduction

> "*To be your own man is a hard business. ... But no price is too high to pay for the privilege of owning yourself.*"
>
> – Friedrich Nietzsche

Many economically active members of a society confront, at some point in time, the choice among employment positions or starting their own business. Why some individuals prefer the uncertainty of the latter option, despite significantly lower future earnings (Hamilton, 2000), is still a matter of controversy. Attitudes towards risk and, more recently, attitudes towards ambiguity have been advanced as possible explanations for entering entrepreneurship. This study investigates risk and ambiguity attitudes of entrepreneurs and non-entrepreneurs facing occupational choice decisions. To that end, we build on the Knightian distinction between risk (known probabilities) and uncertainty (unknown probabilities) (Knight, 1921). We conceptualize ambiguity as an intermediate situation between risk and uncertainty (Wakker, 2010), and we operationalize it through probability intervals (Curley and Yates, 1985).

Past research considers individual risk preferences as an important determinant of entry to entrepreneurship and other entrepreneurial decisions. Entrepreneurs are mainly associated with risk tolerance or lower levels of risk aversion (Kihlstrom and Laffont, 1979; Wu and Knott, 2006). Nevertheless, whether entrepreneurs are ultimately risk lovers or risk averse remains still unresolved (Elston et al., 2005; Elston and Audretsch, 2011; Parker, 2009). Furthermore, entrepreneurship scholars recognize uncertainty as a more realistic and comprehensive construct compared to risk (McMullen and Shepherd, 2006; York and Venkataraman, 2010), yet its effects on entrepreneurial behavior are so far under-investigated. Recently, entrepreneurial scholars have studied empirically ambiguity attitudes of entrepreneurs (Shyti, 2013). Hardenbol (2012) estimates risk and ambiguity atti-

tudes using small-stake lotteries, and finds no difference between students, managers, and entrepreneurs in his setting. In another study, Bengtsson et al. (2012) determine risk preferences using fixed and variable salary choices and ambiguity preferences through a choice between a bet with known probabilities and a bet with unknown probabilities, and they observe less risk and ambiguity aversion for entrepreneurs compared to non-entrepreneurs. Holm et al. (2010) report that entrepreneurs are more willing to accept forms of strategic uncertainty, related to trust and competition, while their attitudes towards non-strategic uncertainty (risk/ambiguity) did not differ compared to lay population.

The aim of our study is to investigate attitudes towards risk and ambiguity in evaluating a new venture. Compared to previous experimental research, our study makes three important contributions. First, we investigate both risk and ambiguity attitudes of entrepreneurs and non-entrepreneurs in the same decision framework, which allows to use risk as a benchmark when studying ambiguity. Second, we cover the entire probability range (from low probabilities to high probabilities), and use different degrees of ambiguity (from low ambiguity to uncertainty) that allows for a more complete study of ambiguity attitudes. Third, consistent with the finding that ambiguity attitudes are context dependent, we use a decision task directly related to individuals' occupational choices, involving high stakes (up to \$500.000), and not a gambling choice-task with relatively small amounts of money.

The main results are as follows. We show that for both entrepreneurs and non-entrepreneurs, risk and ambiguity attitudes are not linear in probabilities: individuals tend to be risk and ambiguity seeking for unlikely outcomes, and risk and ambiguity averse for likely outcomes. This distortion violates Expected Utility Theory predictions, but it is consistent with an inverted s-shape probability weighting function under Prospect Theory. Our findings show that for both risk and ambiguity, entrepreneurs exhibit more optimism compared to non-entrepreneurs.

Moreover, our results suggest that while non-entrepreneurs have similar attitudes towards risk and towards ambiguity in occupational choice decisions, entrepreneurs discriminate between the two conditions, and exhibit more pessimism when facing ambiguity. Findings of our study at the individual level are consistent with results reported in the ambiguity literature based on financial decisions involving monetary lotteries.

The rest of the paper is organized as follows. Section 2 reviews the related literature. Section 3 details the theoretical framework of the decision model. The experimental design and the results are presented in Sections 4 and 5. Section 6 concludes.

2 Background and Related Literature

Although uncertainty constitutes the quintessential condition for entrepreneurship to exist and flourish, most studies treat uncertainty qualitatively and produce theorizing that is insightful, but not immediately useful to understand behavior. Instead, past literature has focused on risk and risk attitudes of entrepreneurs as an important factor in entrepreneurial decisions (Elston et al., 2005; Elston and Audretsch, 2011; Parker, 2009). Yet, for a multitude of reasons, and the heterogeneity of methodologies employed across studies, it remains unsettled whether entrepreneurs are risk lovers or risk averse. Similarly, past efforts aimed at assessing how entrepreneurs perceive ambiguity, relying on psychometric scales (Schere, 1982; Dollinger, 1983; Teoh and Foo, 1997), such as ambiguity intolerance (Frenkel-Brunswik, 1949; Budner, 1962), have provided inconclusive results.

In this paper, we follow Frank Knight's proposition that entrepreneurs are rewarded for bearing uncertainty rather than risk. Knight (1921) made a clear distinction between risk, situations with known probabilities, and uncertainty, sit-

uations with unknown probabilities. In fact, self-selecting into entrepreneurship evokes a setting of decision making under uncertainty, as entrepreneurs are betting on the (unknown) odds that their new venture will be successful. In this regard, Ellsberg (1961) predicts *ambiguity aversion*, observed when individuals prefer known probabilities to unknown probabilities. This is also known as Ellsberg's Paradox, a pattern of behavior inconsistent with Expected Utility Theory[1]. Is it thus plausible that entering entrepreneurship represents a reversal of Ellsberg's Paradox, meaning that entrepreneurs prefer unknown probabilities? What do we know about ambiguity attitudes of entrepreneurs when evaluating new venture options? Do entrepreneurs accommodate ambiguity in their decision/deliberation processes?

Modern decision theories have developed tools to analyze behavioral responses to risk and uncertainty. Among these, Prospect Theory (Kahneman and Tversky, 1979; Wakker, 2010) shows that decision makers are risk seeking for unlikely outcomes, and risk averse for likely outcomes, a distortion known as the inverted s-shape probability weighting function. Under the same framework, Abdellaoui et al. (2011) show that individual attitudes towards risk are distinct from attitudes towards uncertainty (for a review, see Camerer and Weber (1992)).

The key learnings that emerge from this literature are: (1) risk and ambiguity attitudes are distinct; (2) risk and ambiguity attitudes are rich, and not invariant traits, but rather domain-specific and likelihood-dependent; (3) in order to assess behavioral responses to risk and ambiguity it is not sufficient to use only one question, but several questions scanning the probability interval; (4) risk and ambiguity attitudes are not consistent with expected utility maximization.

Recently, only a few empirical papers have addressed ambiguity attitudes of

[1]Ellsberg (1961) suggested a thought experiment concerning two urns, each containing 100 balls. Urn I contains 50 red balls and 50 black balls. Urn II contains 100 balls, each of which could be read or black. If the decision maker correctly guesses the color of a ball drawn from the urn of his choice,

entrepreneurs, primarily tapping into the existent literature on decision making. Hardenbol (2012) estimates risk and ambiguity attitudes using binary choices between lottery options, with gains up to $40, and finds no difference between students, managers, and entrepreneurs.

Bengtsson et al. (2012) investigate risk and ambiguity for entrepreneurs and non-entrepreneurs. Risk attitudes are inferred through individuals' choices between a fixed and a variable salary with probability 0.50. Ambiguity attitudes are determined through a single question, based on three-color Ellsberg's example (Ellsberg, 1961), where respondents have to choose between a risky lottery and an ambiguous lottery. Bengtsson et al. (2012) findings are consistent with less risk and ambiguity aversion for entrepreneurs compared to non-entrepreneurs.

Holm et al. (2010) compare 700 entrepreneurs and 200 non-entrepreneurs based in China. They study risk and ambiguity attitudes using several binary choices between monetary lotteries. In order to determine ambiguity attitudes, they use two decisions tasks, one with unknown probabilities, and the other one with probabilities between .25 and .75, which natural center of both is 0.50. They observe that entrepreneurs were accepting more situations of uncertainty involving competition and trust compared to non-entrepreneurs. However, entrepreneurs risk and ambiguity attitudes did not differ compared to the control group.

These studies advance the debate on entrepreneurial attitudes towards ambiguity, but they fail on at least one of the points mentioned above. Bengtsson et al. (2012) used a single question to estimate ambiguity attitudes, and only one probability point to determine risk attitudes. Both Holm et al. (2010) and Hardenbol (2012) base their experiment on the Holt and Laury (2002) method, which builds on Expected Utility Theory, thus providing biased estimates for both risk and ambiguity attitudes, not taking into account the richness of these attitudes. Hardenbol (2012) used relatively low stakes in his study. Classical experimental

economics tools for measuring risk preferences are of questionable validity when it comes to predicting behavior for real business decisions. Abstract representations of decision problems and error may all be factors contributing to this failure. Moreover, as empirical evidence shows, EUT is a fallible guide in understanding decision making, as individuals consistently violate EUT predictions.

Given the importance of ambiguity in entrepreneurship, we aim to address ambiguity in decision making with more powerful models, robust to deviations from EUT. An established behavioral model that takes into account ambiguity and ambiguity preferences in decision making is Prospect Theory (Kahneman and Tversky, 1979; Wakker, 2010). We investigate ambiguity attitudes of entrepreneurs and non-entrepreneurs facing an entrepreneurial project.

3 Theory: Behavior under Risk and Ambiguity

Occupational choice decisions can be captured through individuals' preferences between an entrepreneurial project with uncertain outcomes and a sure employment. Accordingly, using Kihlstrom and Laffont (1979)'s decision model we present the individual with a high-profit business prospect and demand his evaluation in terms of a trade off with wage-equivalent. Thus, the decision maker's evaluation represents an opportunity cost of the project, for which he would rather take the job. In terms of preferences, stating a *wage equivalent* implies that for any lower value than the declared annual salary, the individual would prefer the entrepreneurial project, and for any higher value than the declared annual salary, the individual would prefer the job employment. We assume employment contracts not to be contingent to any future event, which is consistent with Kihlstrom and Laffont (1979) theoretical setting, where economic agents can choose between an employment with risk free wage, and entering entrepreneurship, thus facing risky (uncertain)

income prospects[2]. Without putting any further structure to the problem, one could expect the entrepreneur to demand a higher economic incentive in order not to choose the business opportunity.

Weighting Functions for Risk and Ambiguity

Under Prospect Theory (Kahneman and Tversky, 1979), the value of a risky prospect, P, that gives outcome X with probability p, and 0 otherwise, depends on the decision maker's utility function, $U(.)$, and probability weighting function under risk, $f_r(.)$. On the other hand, a job, J, that pays wage W, and is relatively risk-free, will be valued by the decision maker uniquely through his utility function, $U(.)$. The utility of the prospect, $U(P)$, and the utility of the job, $U(W)$, are respectively given by the equations 1 and 2:

$$U(P) = U(x) * f_r(p) \tag{1}$$

$$U(J) = U(W) \tag{2}$$

In our framework, the *wage equivalent*, WE, represents for the decision maker an indifference point between the project and the employment. This implies equal utilities for the project and the job:

$$U(x) * f_r(p) = U(WE) \tag{3}$$

In the case of a business prospect with ambiguous likelihood of success, the decision maker evaluates the prospect using the same utility function, $U(.)$, and a different weighting function, $f_a(.)$. The indifference equation has an ambiguous probability, $[\underline{p}, \overline{p}]$, and the weighting function for ambiguity, $f_a([\underline{p}, \overline{p}])$:

[2]In this theory, in equilibrium, less risk-averse agents become entrepreneurs and more risk-averse agents become wage-earners.

$$U(x) * f_a([\underline{p}, \overline{p}]) = U(WE) \tag{4}$$

Under Prospect Theory, risk attitudes of decision makers are captured partially from the shape of the utility function, and partially from the weighting function. Ambiguity attitudes of decision makers are evaluated in a similar way.

While the literature offers a variety of weighting functions (Kahneman and Tversky, 1979; Goldstein and Einhorn, 1987; Prelec, 1998; Abdellaoui et al., 2010), some specifications have the advantage of separating between two psychological phenomena through two different parameters: insensitivity (α) and elevation (β)(Prelec, 1998; Abdellaoui et al., 2010). Insensitivity implies that individuals' do not sufficiently discriminate between probability levels, while elevation reflects pessimism in the transformation of probabilities. Several studies have demonstrated the insensitivity phenomenon for both risk and ambiguity (Tversky and Fox, 1995; Abdellaoui et al., 2011).

Therefore, we expect that a decision maker would have different α and β parameters for risk and ambiguity. Moreover, we prospect that entrepreneurs will exhibit different α and β parameters compared to non-entrepreneurs. In this paper, we adopt Prelec (1998) specification:

$$f(p) = (exp(-(-ln(p))^{\alpha}))^{\beta} \tag{5}$$

4 Experimental Design

4.1 Procedure

The experiment took place during the period July-November 2013. Participants were recruited through the Qualtrics platform. Individuals were invited to partic-

ipate to the study by receiving a link via e-mail. Respondents were compensated upon completion of the web-based study that took about 10 minutes. As per Qualtrics records, 2.101 participants opened the link to the study. After eliminating incomplete answers as well as subjects that didn't provide accurate answers to the attention filters in the experiment, we were left with 350 complete questionnaires used in the analysis.

The purpose of our study was to provide evidence on how entrepreneurs and non-entrepreneurs will differ in terms of ambiguity attitudes, thus the initial request addressed to Qualtrics was to recruit an equal number of entrepreneurs and non-entrepreneurs. However, after multiple questions that accurately refine the occupational choice/status of the respondents, we ended up having 185 non-entrepreneurs and and 165 business owners. Precisely, to classify individuals into these groups, we used the question: "Do you currently own a business?", to which individuals answered by "yes" or "no". Other classifications and subsequent checks were performed on other demographic information. Individuals were randomly selected from Qualtrics available panels and subsequently invited to participate to our study.

4.2 Participants

Our sample is relatively balanced in terms of gender (52% males, 48% females), and work experience (50% of the sample has more than 15 years work experience). In terms of education, 22.4% of the entrepreneurs have a bachelor's degree; 14% have a master's degree; and 53% hold degrees below the bachelor level. Among non-entrepreneurs, 25.4% have a bachelor's degree; 8% of non-entrepreneurs have a master's degree; and 63% hold degrees below the bachelor level. The average age is 40.6 years old. The average annual income for entrepreneurs is $71.000; and $50.400 for non-entrepreneurs. 23% of entrepreneurs and 10% of non-entrepreneurs

earn annual income above $100.000. Annual income from business, $72.000 on average, is quite scattered: 39.4% declares to earn below $30.000 in a year; 30% above $100.000, and 13.9% above $200.000. Among respondents, 48.85% declare to have started a business before (of which, 38 non-entrepreneurs); among the 133 entrepreneurs with previous start-up experience 57.14% have started two or more ventures in the past. A summary of demographics is available in Table 1).

Table 1: Summary of Dependent Measures by Performance Group

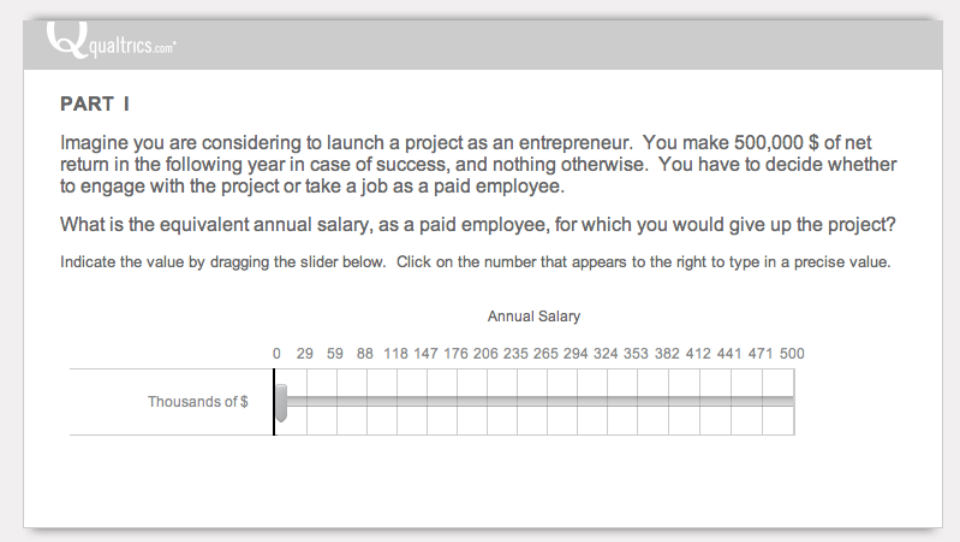
Variable	**Entrepreneurs**	**Non-Entrepreneurs**
N	**165**	**185**
Age	40.3	40.8
Female	80	88
Married	84	95
Started a Business Before	133	38
Average Annual Income ($000)	71	50.4
Individual Income (above $\$100K$)	10.8%	5.4%
Firm Income (above $\$100K$)	23.6%	-
Work experience ($>$ 15 years)	49%	50%
Education (bachelor's degree)	22.4%	25.4%

4.3 Experimental task

The web-based experiment was programmed on Qualtrics. Two small scale pre-tests were run beforehand. Following these pre-tests, we made several small changes to the original version of the study concerning the number of questions and the presentation.

We designed a scenario-based experiment. Respondents were presented with 14 hypothetical scenarios, displayed on the screen one at a time. In each scenario, respondents confronted a situation where they had to choose between a future entrepreneurial project expected to yield a profit of $500.000 in case of success and 0 otherwise, and a position as a paid employee. Respondents were asked to indicate for which amount of annual salary in thousands of $, as a paid employee, they

Figure 1: Example of choice task for Uncertainty



would give up the entrepreneurial project (as in Figure 1). This setup allowed us to estimate risk and ambiguity attitudes, for decisions directly related to occupational choices. Moreover, this method had the advantage to provide all respondents with exactly the same decision situation.

From one scenario to another, we manipulated the chances of success of the entrepreneurial project, holding constant the expected outcome of $500.000. We used one uncertainty scenario, where the chances of success could be anything between 0 and 100%, five risk scenarios, and eight ambiguity scenarios (see Table 2). Participants were presented first with the uncertainty scenario, followed by the risk scenarios, and then the ambiguous scenarios[3].

In addition to the scenarios, participants were asked a series of demographics, as well as questions about their occupational choices, in order to assess whether the respondent was currently a business owner, and whether he or she had experience with entrepreneurial projects in the past.

[3]We aim to further introduce randomization to check for (and avoid) order effects.

4.4 Scenarios

Uncertainty. In the uncertainty scenario, respondents were confronted to the following situation: "Imagine you are launching a project as an entrepreneur. You make $500.000 of net return in the following year in case of success, and nothing otherwise. You have to decide whether to engage with the project or take a job as a paid employee." They were asked to indicate the annual salary, as a paid employee, for which they would give up the project. In this scenario, no information was given concerning the chances of success of the project. This corresponds to a decision situation under uncertainty, where the chances of success could be anything between 0 and 100%.

Risk. In the risk condition, participants were presented with hypothetical scenarios in which the probability of success of the entrepreneurial project was explicitly provided. Five levels of probability were used in the study, respectively 5%, 20%, 50%, 80%, and 95%. In the context, the information about probabilities was presented as follows: "The project you are considering has 20% probability of making $500.000 of net return in the following year". The five levels of probability were chosen in order to scan the entire probability interval, including low probabilities (5%) and high probabilities (95%).

Ambiguity. Ambiguity, defined as imprecise information about the likelihood of success of the project, was operationalized through probability intervals (Curley and Yates, 1985). A probability interval $[\underline{p}, \overline{p}]$ can be described by its *midpoint*, computed as $(\underline{p} + \overline{p})/2$, and its *length*, $(\overline{p} - \underline{p})$. Longer probability intervals correspond to more ambiguity. In the case of risk, the interval has length 0, and the midpoint coincides with the known probability, p.

The ambiguity conditions consisted in three high ambiguity scenarios, in which probability intervals had length .4 and were centered respectively at 20%, 50%, and

80%; three low ambiguity scenarios, with probability interval length 0.2, likewise centered at 20%, 50%, and 80%. We presented also two very low ambiguity scenarios with probability interval length 0.1, respectively centered at 5% and 95%. Note that for extreme likelihood levels, it is not possible to use probability intervals of length 0.2. Throughout the analysis, we will consider the two scenarios with probability interval of length 0.1, together with the three scenarios with probability interval of length 0.2, and we will refer to these five ambiguous scenarios as "low ambiguity".

The ambiguity conditions differed in their degree of ambiguity, given by the length of the probability interval corresponding to the likelihood of success of the project. The ambiguous scenarios were presented to the subjects as: "The project you are considering has between 10% and 30% probability of making $500.000 of net return in the following year".

Table 2: Experiment Stimuli

Scenario	Type	Probability Interval	Midpoint	Payoff($)
1	uncertainty	[0-1.00]	.50	500.000
2	risk	[.05]	.05	500.000
3	risk	[.20]	.20	500.000
4	risk	[.50]	.50	500.000
5	risk	[.80]	.80	500.000
6	risk	[.95]	.95	500.000
7	high ambiguity	[.00 - .40]	.20	500.000
8	high ambiguity	[.30 - .70]	.50	500.000
9	high ambiguity	[.60 - 1.00]	.80	500.000
10	low ambiguity	[.00 - .10]	.05	500.000
11	low ambiguity	[.10 - .30]	.20	500.000
12	low ambiguity	[.40 - .60]	.50	500.000
13	low ambiguity	[.70 - .90]	.80	500.000
14	low ambiguity	[.90 - 1.00]	.95	500.000

Dependent Measures – *Wage Equivalents (WE)*

In this study we use *wage equivalents*, which corresponds to a certainty equivalent approach. More precisely, for each hypothetical scenario, participants were asked to indicate the level of an equivalent annual salary for which they would be indifferent between the entrepreneurial project and an employment position. Participants expressed their choices in each scenario by dragging a slider bar (as in Figure 1). We preferred this approach (asking directly for the equivalent salary)

to a choice-based design (determining the equivalent salary based on several subsequent choices between the project and given salary levels) for two main reasons. First, a choice-based design would have been rather abstract in this setting, since salary negotiations do not normally go through many rounds[4]. Second, the choice-based approach is also long. Asking directly the equivalent salary allowed to reduce the response time, an important aspect in an online experiment. Participants made decisions on each scenario one at a time, and once they validated their choice, they were not allowed to go back and change their answers to previous questions.

5 Results

Our statistical analysis draws on 14 decisions per individual, based on a sample of 165 entrepreneurs and 185 non-entrepreneurs. All reported statistical tests are two-sided, with a level of significance of 0.05. All results hold after controlling for age, gender, education, individual income, and past experience.

We first run a repeated measures ANOVA, with the variable *business owner* (yes/no) as the between-subject factor, and *scenario*, as the repeated measure. The ANOVA model explained a significant proportion of variance ($p < 0.0000$, $F = 37.77$), with an adjusted $R^2 = 0.74$.

The main effects were significant for business owners ($p < 0.0001; F = 16.05$). This suggests that entrepreneurs (business owner = yes) and non-entrepreneurs (business owner = no), provided different wage equivalents. The main effects for scenario were also significant ($p < 0.0000; F = 254.26$): respondents provided different answers across scenarios, meaning they took into account the information about the likelihood of success of the entrepreneurial project. However, one should note that the ANOVA is testing for equality of wage equivalents, WE, across

[4]Each indifference requires an important number of sequential binary choices between project and salary.

experimental scenarios, while the interesting results are seen among comparisons of wage equivalents for risky and ambiguous scenarios with the same likelihood of success. The interaction between business owner and scenario was also found to be significant ($p < 0.0008$; $F = 2.72$), suggesting that entrepreneurs and non-entrepreneurs reacted differently across scenarios.

Entreprenreurs versus Non-Entrepreneurs

In order to further investigate the difference between entrepreneurs and non-entrepreneurs, we compare their stated wage equivalents for each scenario.

Results of pairwise post-estimation ANOVA tests are summarized in Table 3, and presented graphically in Figure 2. These results confirm our initial intuition that entrepreneurs would ask for more money in order to abandon a business prospect. The wage equivalents are higher for entrepreneurs in all experimental conditions, meaning for risk, for low ambiguity, for high ambiguity, and for uncertainty. One can note that the wage difference between entrepreneurs and non-entrepreneurs is more important for the conditions where the entrepreneurial project has a low likelihood of success (50% or less), suggesting that entrepreneurs and non-entrepreneurs react differently to likelihood levels. In terms of risk attitudes these results suggest risk seeking for low probabilities and risk aversion for high probabilities. While this pattern is observed for the entire sample, entrepreneurs are visibly more optimistic than non entrepreneurs in the risk conditions, and very optimistic at lower likelihoods.

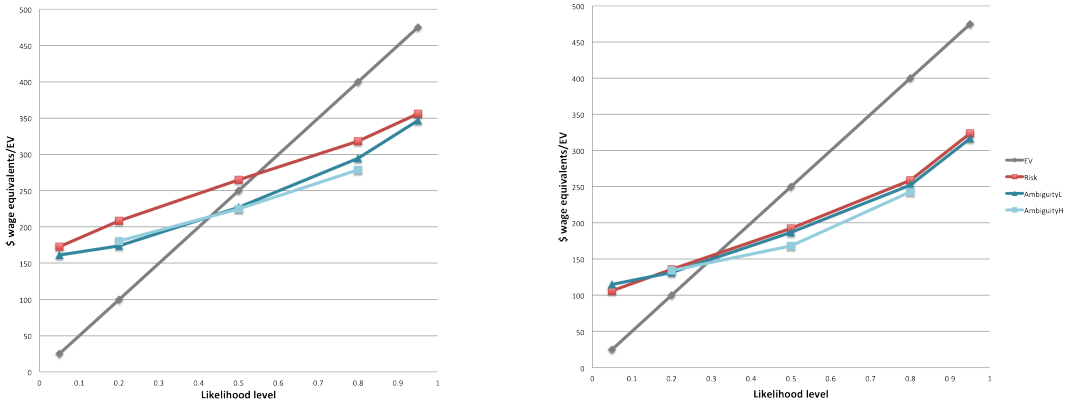
Ambiguity Attitudes versus Risk Attitudes

One important aspect of our analysis is to examine differences in behavioral responses towards risk and ambiguity for the same likelihood level. Since in our study we use the same framework for estimating both risk and ambiguity attitudes, behavior under risk can be used as a benchmark to study behavior under

Table 3: Pairwise Comparisons of Wage Equivalents

Scenario	Type	Likelihood	**WE ENT**	**WE Non-ENT**	**WE Difference**	$t-tests$ $WE_{ent} = WE_{nonent}$
1	uncert	[0-1.00]	247.41	188.89	58.52	0.000
2	risk	[.05]	172.54	106.09	66.45	0.000
3	risk	[.20]	208.18	136.09	72.10	0.000
4	risk	[.50]	264.64	192.72	71.92	0.000
5	risk	[.80]	317.95	258.91	59.04	0.000
6	risk	[.95]	355.84	323.57	32.27	0.031
7	ambh	[.00 - .40]	180.41	134.05	46.35	0.002
8	ambh	[.30 - .70]	224.92	168.23	56.69	0.000
9	ambh	[.60 - 1.00]	278.49	242.77	35.72	0.017
10	ambl	[.00 - .10]	161.10	114.97	46.13	0.002
11	ambl	[.10 - .30]	173.91	131.68	42.23	0.005
12	ambl	[.40 - .60]	227.07	186.79	40.28	0.007
13	ambl	[.70 - .90]	294.20	52.45	41.75	0.005
14	ambl	[.90 - 1.00]	346.77	316.56	30.21	0.044

Figure 2: Wage Equivalents Entrepreneurs and Non-Entrepreneurs



(a) WE of Entrepreneurs

(b) WE of Non-Entrepreneurs

ambiguity. By definition, a decision maker is ambiguity neutral if, when facing an ambiguous probability, $[\underline{p}, \overline{p}]$, his behavioral response is exactly the same as when facing a risky situation with the probability, p, or the midpoint, $[\underline{p}, \overline{p}]/2$, of the probability interval. Therefore, the comparison of the ambiguous and risky experimental conditions, with the same likelihood level, can be used as a test for attitudes towards ambiguity.

More precisely, our framework allows to classify a respondents' risk attitudes as averse, neutral, or seeking, based on declared wage equivalents. Moreover, at the corresponding likelihood levels, we can classify ambiguity attitudes compared to

risk attitudes, based on wage equivalents respectively for ambiguity and for risk. If the decision maker gives lower (higher) wage equivalents for the ambiguous project, compared to the wage equivalent for the risky project, then the decision maker is ambiguity averse (seeking). If the decision maker gives equal wage equivalents for the ambiguous project and the corresponding risky project, then the decision maker is ambiguity neutral.

In what follows, we present the analysis of pooled data, comparing risk and ambiguity attitudes. Then we proceed to study behavioral responses to risk and ambiguity within the two groups, entrepreneurs and non-entrepreneurs. Note that, to study ambiguity attitudes, the comparisons of interest are all the combinations among risk, low ambiguity, high ambiguity, and uncertainty, at the same likelihood level. Table 4 provides a summary of the pairwise comparisons of the ANOVA contrasts between all experimental conditions with same likelihood levels, for the entire sample, and separately for entrepreneurs and non-entrepreneurs. Figure 3 is a graphical representation of wage equivalents across experimental conditions for entrepreneurs and non-entrepreneurs.

Pooled data. At the aggregate level, comparing risk and low ambiguity, we find that for extreme probabilities we cannot reject the equality between wage equivalents. Our results show that for extreme probabilities, ambiguity does not matter: if an event is very unlikely, or almost sure to happen, the precision of the probabilistic information, may not change decision makers perceptions. These observations suggests that for very low ambiguity levels (length of the interval 0.1) respondents did not differentiate between risk and ambiguity. Comparisons between risk and low ambiguity for likelihood levels centered at 0.20, 0.50, and 0.80, give highly significant results: even low ambiguity in probabilities generates more pessimistic answers in terms of wage equivalents. Likewise, all comparisons between risk and

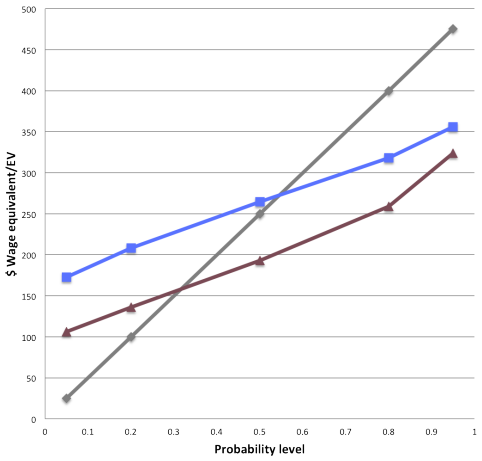
high ambiguity generate highly significant results (highest $p-value < 0.016$). This suggests that, at aggregated level, respondents exhibited more pessimism towards ambiguity compared to risk for all intervals of length 0.2 or longer. As a general behavioral pattern, when asked to state a wage equivalent in order to not to choose the entrepreneurial project, individuals give more pessimistic responses (smaller wage equivalents), when likelihood of success is ambiguous. One important finding of this set of analysis, is that decision makers react differently depending on the likelihood level, for risky and ambiguous project, a behavioral pattern that is not consistent with Expected Utility Theory that assumes that probabilities are treated linearly.

Entrepreneurs. A closer look at the entrepreneurs responses confirm the findings at the aggregate level, but the differences in wage equivalents (WE Contrast) across conditions are more important. More specifically, comparing risk scenarios to low and high ambiguity scenarios induces more pessimism in wage equivalents, all highly significant results at 1% significance level (highest $p - value < 0.007$, for a WE Contrast = -23.75). As at the aggregate data analysis, for extreme likelihood levels, wage equivalents for risk and ambiguity are not significantly different.

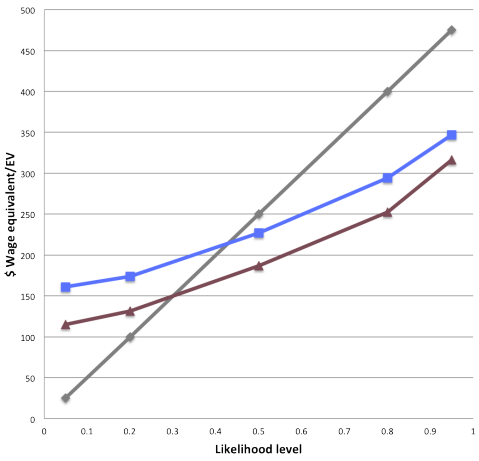
Table 4: Ambiguity Attitudes versus Risk Attitudes

Comparison	**Midpoint**	**Pool Data WE Contr.**	t-tests $WE_i = WE_j$	**ENT WE Contr.**	t-tests $WE_i = WE_j$	**Non-ENT WE Contr.**	t-tests $WE_i = WE_j$
AmbL vs Risk							
10 vs 2	[0.5]	-0.70	0.908	-11.44	0.194	8.88	0.286
11 vs 3	[.20]	-18.49	0.002	-34.27	0.000	-4.41	0.597
12 vs 4	[.50]	-20.85	0.001	-37.57	0.000	-5.93	0.476
13 vs 5	[.80]	-14.61	0.016	-23.75	0.007	-6.45	0.438
14 vs 6	[.95]	-7.98	0.187	-9.07	0.304	-7.01	0.400
AmbH vs Risk							
7 vs 3	[.20]	-14.17	0.019	-27.78	0.002	-2.03	0.807
8 vs 4	[.50]	-31.67	0.000	-39.72	0.000	-24.49	0.003
9 vs 5	[.80]	-27.13	0.000	-39.45	0.000	-16.14	0.052
AmbL vs AmbH							
11 vs 7	[.20]	-4.32	0.476	-6.50	0.461	-2.37	0.776
12 vs 8	[.50]	10.82	0.074	2.15	0.808	18.56	0.026
13 vs 9	[.80]	12.53	0.038	15.71	0.075	9.69	0.244
Risk vs Unc.							
4 vs 1	[.50]	10.15	0.093	17.23	0.051	3.83	0.645
AmbL vs Unc.							
12 vs 1	[.50]	-10.70	0.077	-20.34	0.021	-2.10	0.801
AmbH vs Unc.							
8 vs 1	[.50]	-21.52	0.000	-22.48	0.011	-20.65	0.013

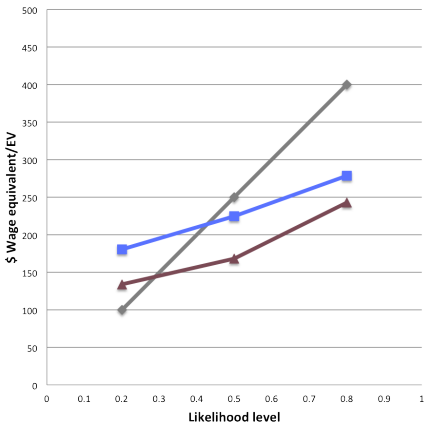
Figure 3: Wage Equivalents for all Conditions



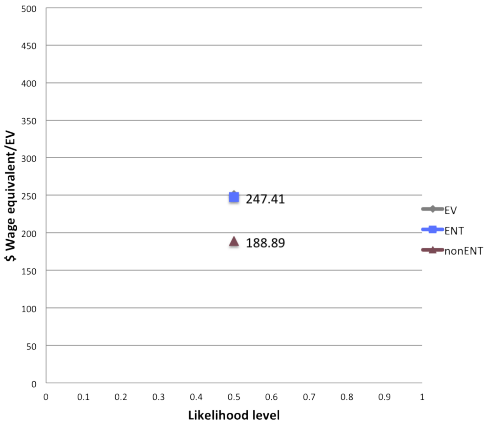
(a) WE for Risk



(b) WE for Low Ambiguity



(c) WE for High Ambiguity



(d) WE for Uncertainty

Interestingly, uncertainty (no information about likelihood of success of the project) compared to both low and high ambiguity conditions, yields more optimistic wage equivalents (respectively, WE contrast -20.34, $p-value < 0.021$, and -22.48, $p-value < 0.011$) (see Table 4 for a summary for entrepreneurs within-subject analysis and Figure 2 for a graphical representation).

Non-Entrepreneurs. The within-subject analysis for the non-entrepreneur group gives surprising results (summarized in Table 4, and displayed in Figure 2).

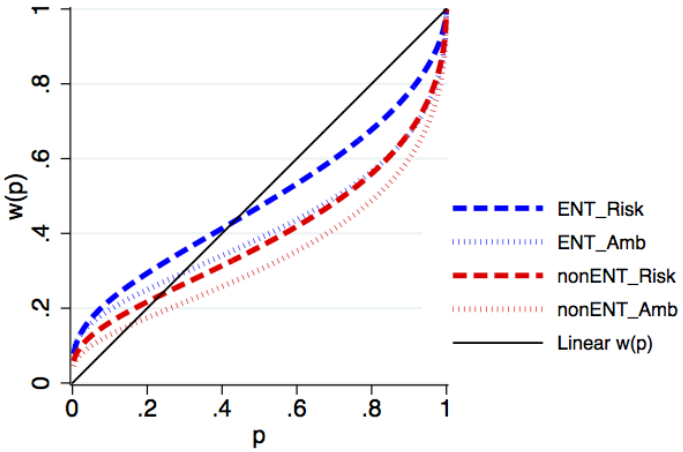
The analysis of ambiguity attitudes for non-entrepreneurs shows that in general, the stated wage equivalents for risky and ambiguous scenarios, at the same likelihood level, are not significantly different. Non-entrepreneurs do not seem to discriminate between risk and ambiguity, thus imprecision in probabilities does not induce optimism or pessimism in their behavioral response.

The only significant comparisons are always at mid-range likelihood levels (0.50). Precisely, high ambiguity at 0.50 likelihood level leads to most pessimistic wage equivalents from non-entrepreneurs. They are more optimistic for risk (higher wage equivalents) then for high ambiguity (WE contrast -24.49, $p-value < 0.003$). Non-entrepreneurs exhibit more optimism also for low ambiguity compared to high ambiguity (WE contrast 18.56, $p-value < 0.026$). Finally, the stated wage equivalents by non-entrepreneurs exhibit more optimism for uncertainty compared to high ambiguity (WE contrast -20.65, $p-value < 0.013$). Taken together, these results suggest that the only situation where non-entrepreneurs exhibit pessimism for ambiguity is in the high ambiguity condition for likelihood 0.50, while low ambiguity, and uncertainty are treated in the same way as risk at all likelihood levels.

Weighting Functions for Risk and Ambiguity

We extend our analysis to estimate parametric weighting functions for risk and am-

Figure 4: Weighting Functions for Entrepreneurs and Non-Entrepreneurs, for Risk and Uncertainty



biguity (Kahneman and Tversky, 1979; Wakker, 2010), assuming a concave utility function for all subjects[5]. Individual estimates of Prospect Theory parameters confirm the general model-free findings, and are consistent with the ANOVA tests. Mean maximum likelihood estimates of the weighting function parameters, for risk and ambiguity, are presented in Table 5 for entrepreneurs and non-entrepreneurs. These findings suggest that both groups are risk and ambiguity seeking for low likelihood outcomes, whereas for high likelihood, behavior changes towards aversion, for both risk and ambiguity.

In particular, we find a similar pattern of insensitivity across groups, with non-entrepreneurs slightly more insensitive, smaller α parameter for risk. Ambiguity contributes to increase insensitivity, a finding that confirms past results (Abdellaoui et al., 2011; Wakker, 2010). Elevation, the β parameter, is smaller for entrepreneurs, representing more optimism. Both entrepreneurs and non-entrepreneurs are more more optimistic for risk (smaller β), and ambiguity con-

[5]We fixed the parameter of a power function at 0.80. In this regard, we may speculate that one can detect differences also in the utility function of entrepreneurs and non-entrepreneurs, and we think this could be an interesting question to address experimentally.

tributes to pessimism, increasing β. However, entrepreneurs are more optimistic than non-entrepreneurs for both risk and ambiguity. Figure 4 is a graphical representation of these findings.

Table 5: Weighting Function Parameters for Risk and Ambiguity

	Entrepreneurs	**Non-Entrepreneurs**
N	**165**	**185**
Risk		
Insensitivity - α_r (std. dev.)	0.58 (0.59)	0.48 (0.36)
Elevation - β_r (std. dev.)	0.93 (0.64)	1.21 (0.73)
Ambiguity		
Insensitivity - α_a (std. dev.)	0.45 (0.35)	0.45 (0.33)
Elevation - β_a (std. dev.)	1.12 (0.59)	1.41 (1.41)

Robustness Checks

In order to evaluate the differences between the mean parameters for entrepreneurs and non-entrepreneurs we construct *extreme groups*, using a more restrictive and multidimensional definition of entrepreneurship. The non-entrepreneurial extreme group consist in respondents that do not currently own a business and were never exposed to entrepreneurial activities: never owned a business, started a business, or were involved in co-founding activities. The entrepreneurial extreme group consist in individuals that were exposed to multiple experiences as entrepreneurs: either started a business, were involved in co-founding activities, and currently own a business. A graphical representation is displayed in Figure 5

Parameter estimates of these groups increase the differences that we observe in the one-dimension sample split. Results are represented in Table 6.

Figure 5: Extreme groups: Weighting Functions for Risk and Ambiguity

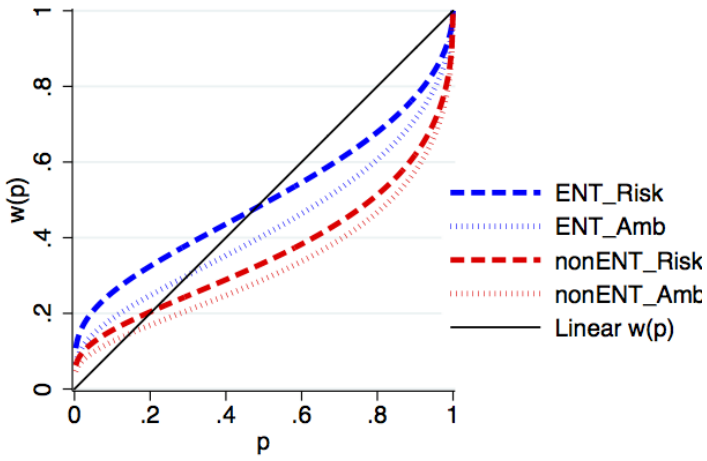


Table 6: Weighting Function Parameters for Risk and Ambiguity - Extreme Groups

	Entrepreneurs	**Non-Entrepreneurs**
N	**52**	**59**
Risk		
Insensitivity - α_r (std.)	0.54 (0.39)	.44 (0.29)
Elevation - β_r (std.)	0.87 (0.59)	1.29 (0.71)
Ambiguity		
Insensitivity - α_a (std.)	0.52 (0.36)	0.43 (0.29)
Elevation - β_a (std.)	1.09 (0.57)	1.45 (1.08)

6 Discussion and Conclusions

In business contexts entrepreneurs are seldom in situations where they are able to estimate an objective probability of success (risk), or in situations of total absence of information (complete ignorance or radical uncertainty). Hence, many entrepreneurial decisions are generally subject to ambiguity, or imprecise information about probabilities of success.

Our study contributes to the entrepreneurship literature by focusing on entrepreneurs' ambiguity attitudes. The novelty of our approach consists in investigating risk and ambiguity attitudes of entrepreneurs and non-entrepreneurs, within

the same decision framework and a homogeneous scale, using risk as a benchmark for ambiguity attitudes. Given the context-dependent feature of risk and ambiguity preferences, our design allows more precision in the analysis such preferences. For example, a high-tech entrepreneur may engage in developing an application for smart phones, although the probabilities of success are unknown, and in the same time he may refrain from betting on an Ellsberg-type lottery with unknown probabilities of winning, as most people do.

Moreover, with our design we assess behavioral responses to risk and ambiguity scanning the probability range, given that individuals do not react in the same way to high and low likelihood levels. The richness of attitudes towards risk and ambiguity is a well-established fact in the literature: people overweight low likelihoods and underweight high likelihoods. Thus, using only one question with only one likelihood level does not allow to draw conclusions on the overall pattern of preferences or to make predictions on individual behavior. For example, it is still a matter of controversy whether entrepreneurs fail because they try too hard when chances of success are low (over-entry in markets), or because they do not try hard enough when chances of success are high (ex., Yahoo!'s lost vision...).

In this study, we address as well degrees of ambiguity. If ambiguity is about imprecise information, the degree of imprecision may bear some relevance in the way it affects behavior. Past experience or expertise in a given context may mitigate the effects of ambiguity, reassuring decision makers about what to expect.

Administering the experiment through online channels could present a limitation about the quality of the data, due to the lack of control and distance between experimenter and subjects, attention problems, etc. However, through the data obtained, our results are consistent with findings from laboratory experiments in decision making, suggesting that the online channel did not provide unreliable data. One may also question the use of hypothetical outcomes in our study, at

least from the perspective of real incentives. Given the nature of our framework, it would have been impossible to design a laboratory experiment and implement real incentives.

The data that we obtain through an online experiment reveal rich patterns of risk and ambiguity attitudes, for both entrepreneurs and non-entrepreneurs: individuals overweight low likelihoods and underweight high likelihoods. Results suggest that entrepreneurs are in general more optimistic than non-entrepreneurs, for both risk and ambiguity. However, entrepreneurs adjust downwards their expectations when facing ambiguity compared to risk, while non-entrepreneurs do not discriminate between risk and ambiguity conditions. More generally, under *uncertainty*, the condition with no likelihood information at all, wage equivalents are on average higher, compared to both low and high ambiguity conditions. *Ambiguity*, or the imprecision in the likelihood information, does somehow contribute to more pessimism compared to uncertainty. It seems plausible, that if people are not aware of the uncertainty characterizing a situation, they are naturally more optimistic, whereas the imprecise probabilistic information provided, may contribute to increasing individual's awareness for the uncertainty itself. Degrees of ambiguity are also perceived differently, as more ambiguity yields more pessimism. For extreme probabilities, small ambiguity may not matter: if an event is nearly impossible to happen, or almost a sure deal, the precision of the probabilistic information, may not change decision makers behavior. *Risk*, compared to ambiguity, yields higher wage equivalents across groups. Thus, shifting from conditions of risk, to conditions of ambiguity may generate some "discomfort" in the decision making process. Entrepreneurs' different attitudes towards risk compared to ambiguity, or their pessimistic response adjustment to imprecise information, may be rooted in different cognitive mechanisms when deliberating about risky and ambiguous business prospects.

Entrepreneurship is an important social phenomenon. In order to design more effective policies and dedicated programs, it becomes relevant to policy makers to understand how entrepreneurial profiles evaluate new business opportunities, which propensities push individuals to engage with new projects, what are entrepreneurs' wage expectations, and how risk and ambiguity impact these decision processes.

Our findings contribute to the ongoing debate on the role of uncertainty in entrepreneurial decision making. Alternative explanations, not addressed in our study, may correlate to our findings, i.e., overconfidence, self-efficacy, locus of control, etc. However, unobservables do not preclude the importance of ambiguity and subjective reactions to it. Further investigations, with more refined designs, can include additional variables, as psychological traits, and expand the focus to the domain of losses and other business decisions.

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