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What is risk to managers?☆

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ABSTRACT

In an online experiment with a sample of 4287 managers from small- and medium-sized enterprises in Denmark, we present participants with scenario-dependent outcomes of a hypothetical investment prospect and elicit their perception of risk and their perception of the investment's attractiveness (as a proxy for investment preferences). The experimental data is merged with a set of background variables on the company from the Danish registry which allows controlling for firm-specific effects. We find that risk perception is driven by the likelihood and the return associated with the worst-case scenario as well as the size of the required investment. Furthermore, we provide evidence that managers' perception of the project's attractiveness is significantly associated with their individual-level risk preferences and the interaction effect between risk preferences and risk perception. This implies that not only the characteristics of the different scenarios but also individuals' risk preferences play an important role when assessing the attractiveness of a business opportunity.

1. Introduction

Risk is of paramount importance in many economic decisions, including the decisions made by business managers to pursue or turn down business investments. Decision-making under risk and uncertainty has been among the most actively pursued avenues in the literature on judgment and decision-making. From day one, research on decision-making under risk and uncertainty has been characterized by its interdisciplinarity (see, e.g., Loewenstein et al., 2001). The strong normative benchmark set by (subjective) expected utility theory (von Neumann and Morgenstern, 1944; Savage, 1954) inspired many theoretical and empirical contributions from both economists and psychologists. The identification of deviations from the (subjective) expected utility model, in turn, has contributed to the development of alternative models and conceptualizations of risk including (cumulative) prospect theory (Kahneman and Tversky, 1979; Tversky and Kahneman, 1992) and other rank-dependent expected utility models (see, e.g., Harless and Camerer, 1994; Starmer, 2000).

Despite risk being one of the key building blocks of (financial) economic and psychological theories of choice, there is a lack of agreement as to how "risk" should be defined (see, e.g., Weber, 1988; Brachinger and Weber, 1997; Hertwig et al., 2018). Several empirical results point toward a mismatch of common definitions of risk (such as, e.g., variance) and the way people *perceive* risk (see, e.g., March and Shapira, 1987; Weber and Milliman, 1997; Veld and Veld-Merkoulova, 2008; Holzmeister et al., 2020, 2022; Zeisberger, 2022a,b). The fact that not even experts in the realms of risk analyses share a common understanding of how risk should be conceptualized and described raises the question of how to effectively communicate risk (see, e.g., Fischhoff, 1995; Kling et al., 2022; Stefan et al., 2022), a question that is particularly relevant in a management context.

As set forth by Slovic (1999), "[r]isk is a subtle concept that has multiple meanings. People (including experts) use the work [sic!] risk inconsistently, sometimes using it to mean a hazardous activity [..], sometimes to mean probability [..], sometimes to mean consequence [..]". A further aspect that complicates reconciling the insights gained from research on judgment and decision-making under risk is that terms such as risk preferences, risk perceptions, and risk-taking are not consistently—and sometimes even synonymously—used (see, e.g., Holzmeister et al.,

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2022).[1] Economists and psychologists have been starting from different conceptualizations of risk, giving rise to different measurement traditions (see, e.g., Hertwig et al., 2018; Mata et al., 2018). Economists typically model risk through the curvature of a decision-makers utility function (Arrow, 1965; Pratt, 1964) and rely on incentivized behavioral measures to elicit revealed preferences (see, e.g., Charness et al., 2013). By contrast, psychologists commonly treat risk as a multi-faceted psychometric construct (see, e.g., Slovic, 1972; Fischhoff et al., 1978; Slovic et al., 1982) governed by intuitive judgments—*risk perceptions*—and tend to rely more on the stated-preference tradition. As such, many contributions to the economics literature treat risk preferences as the only determinant of risk-taking behavior and ignore risk perceptions; on the contrary, many contributions to the psychology literature take no account of preferences and treat perceptions as the driving force behind risky choices. More recent developments in the judgment and decision-making literature acknowledge the relevance of both preferences and perceptions and strive toward bridging the gap between the two worlds (see, e.g., Nosić and Weber, 2010; Frey et al., 2017; Hertwig et al., 2018; Mata et al., 2018).

The conceptualizations of risk in the management literature are conflated in a similar way, with several contributions emphasizing different aspects of risk. An integral contribution to the literature on the conception of "risk" in managerial decision-making is the paper by March and Shapira (1987). The article synthesizes the evidence put forward by Shapira (1986), relying on interviews with 50 American and Israeli executives, and MacCrimmon et al. (1986), relying on interviews with 129 executives in Canadian and American firms as well as survey responses from 509 executives from these countries. The synopsis by March and Shapira (1987) suggests that the processes that induce risk-taking in a business context do not align with classical decision theory, which predicts that choice involves a calculation and trade-off between the expected return (mean) and risk (variance) of the probability distributions over potential outcomes. Furthermore, March and Shapira (1987) highlight that the conception of risk as variance does not pertain to actual managerial decisions. Three key findings about managerial risk conception stand out. First, both Shapira (1986) & MacCrimmon et al. (1986) suggest that positive outcomes associated with managerial decisions are not considered important aspects of risk. This implies that, in assessing risk, managers tend to neglect a potentially significant part of the variation in outcomes. Second, the respective probabilities of potential outcomes only appeared to be a risk factor for some managers, and, even for those, the magnitudes of the negative outcomes were more salient. For instance, Shapira (1986) found that when asked to evaluate uncertain prospects, 80% of managers requested information about the "worst outcome" or "maximum loss". Third, managers expressed uncertainty about the possibility of quantifying risk as a single construct. Most felt that risk ought to be quantified but also noted that this was not what they would do to evaluate risk.

Since the contribution by March and Shapira (1987), the progress made in understanding risk perception and the importance of risk conception for a firm's risk-taking has been limited primarily to conceptual work drawing on previous papers in a somewhat piecemeal manner. Most notable in this vein are papers which have as one of several foci the provision of one overarching definition of risk. Sitkin and Pablo (1992) conceptualize risk as the uncertainty about the realization of significant and/or disappointing outcomes. Mullins and Forlani (2005), drawing on psychological insights from Yates and Stone (1992), propose that – while the chance for gains is what motivates actors to engage in risk-taking – risk itself relates to the likelihood of realizing a considerable loss. Sanders and Hambrick (2007) suggest that investments are risky when potential outcomes are consequential, involve the possibility of extreme losses, or vary widely. Sanders and Hambrick (2007) also argue that an investment opportunity might be risky in one while being non-risky in another dimension and, thus, indirectly challenge March and Shapira's (1987) interpretation of the magnitude of the worst possible outcome as being almost the only aspect of importance to managerial risk assessments.

Despite excellent empirical and conceptual work in various disciplines concerned with the notion of risk, the above account demonstrates that the understanding of managers' conception of risk is at best fragmentary. While various determinants of "risk" have been proposed, comprehensive empirical evidence as to which factors drive managers' perception of risk in a business context is lacking. Furthermore, the implications for investment preferences of potential drivers of risk perception have been opaque and suffer from a lack of integration in a controlled setting. Although it appears intuitively evident that more risk-tolerant managers would be less likely to be scared off by opportunities that appear risky and therefore perceive them as being more attractive, only a few attempts have been made to integrate risk perceptions and risk preferences into one comprehensive model of risk. Sitkin and Weingart (1995) and Nosić and Weber (2010) are among the few studies that explicitly model risk-taking behavior as a function of both risk perceptions and risk preferences. Our paper joins the ranks of contributions to this strand of research, focusing on managerial decision-making. As compared to studies investigating the conceptualization of risk in individual financial decision-making (see, e.g., Holzmeister et al., 2020; Zeisberger, 2022a,b), managerial decisions are of particular importance as they go beyond the individual scope since they affect the company as a whole. In this paper, we seek to consolidate and advance the literature based on the insights gained from a large-scale experiment with business executives. We investigate which aspects of the Knightian definition of risk (Knight, 1921) best describe business managers' engagement with risky investment opportunities.[2] Particularly, it is our goal to better understand *(i)* which attributes of a business opportunity (such as, e.g., potential outcomes, likelihoods, absolute stakes, or the investment horizon) drive managers' perceptions of risk, and *(ii)* how risk perceptions *and* risk preferences translate into investment preferences (proxied by the perceived attractiveness of an investment opportunity).

We address the two research questions sketched above via an online experiment in which 4287 managers of small- and medium-sized enterprises (SMEs) in Denmark assess the risk and the attractiveness of a hypothetical investment opportunity. The

[1] We distinguish between three dimensions of the "risk" construct (see, e.g., Holzmeister et al., 2022): risk perception, risk preferences, and risk-taking behavior. *Risk perception* is defined as a decision-maker's judgment of how risky a prospect is in terms of situational uncertainty (see, e.g., Slovic, 1987; MacCrimmon and Wehrung, 1990; Jia et al., 1999). *Risk preferences* are defined in terms of a binary preference relation on risky prospects and are typically conceived of as a latent trait and stable dispositional attribute (see, e.g., von Neumann and Morgenstern, 1944; Fischhoff et al., 1981; Friedman et al., 2014). As opposed to perceptions and preferences, *risk-taking* pertains to the behavioral dimension of "risk" and describes the actual decisions and choices made (see, e.g., Schoemaker, 1993; Sitkin and Weingart, 1995; Weber et al., 2002).

[2] Note that our contribution is limited to the Knightian definition of risk, i.e., measurable uncertainty. Knightian ambiguity, i.e., unmeasurable uncertainty, is beyond the scope of our paper. In real-world settings, however, managers will be regularly confronted with ambiguity, making it an important type of uncertainty in strategic decision-making. Recent contributions to the management literature emphasize the relevance of ambiguity in strategic decisions, discuss the challenges faced in terms of structuring and optimizing decision problems, and propose concepts to address these problems as a basis for practical decisions (see, e.g., Arend, 2020; Ramoglou, 2021; Aggarwal and Mohanty, 2022).

business projects are scaled by firm size and vary across managers in terms of the required size of the investment and the time with income from the investment, and four parameters (including the investment's net loss/gain, the yearly internal rate of return, the number of years to break-even, and the likelihoods of outcomes) determined by three scenarios (worst case, base case, and best case).

Our experiment provides several insights. First, managers, on average, perceive the risk of an investment opportunity to increase with the size of the required investment, indicating that managers do not only take into consideration relative measures but also integrate the project's absolute stake into their risk assessment. Second, we provide evidence for managers' perception of risk being driven by the potential downsides of a business project, but not its upsides: We find that both higher likelihoods and higher magnitudes of the worst-case outcome induce managers to perceive business opportunities to be more risky. Notably, however, we do not find evidence for the interaction between likelihoods and magnitudes being systematically related to risk perception, challenging expectation-based conceptions of risk. Third, managers' assessment of the project's attractiveness significantly correlates with their perception of risk. Yet, the impact of the various project attributes on risk and attractiveness judgments turns out not to be symmetric: While managers' perception of the project's attractiveness is not affected by the size of the required investment, it does not only relate to the returns and likelihood of the worst-case scenario but also to the returns and likelihoods of the base-case and best-case scenarios. Fourth, we provide evidence that managerial decision-making processes are not only affected by subjective conceptions of project characteristics but are also governed by a manager's individual-level risk preferences. Particularly, we find that, on average, managers who are highly risk-averse tend to perceive the project as relatively unattractive *per se*, irrespective of the extent to which the project is perceived to be risky.

2. Methods

We conducted a large-scale non-incentivized online experiment with chief executive officers of SMEs in Denmark.[3] Experimental participants were presented with a hypothetical business opportunity, varying in several key attributes that may enter managers' assessment of risk and attractiveness of the business opportunity. In particular, managers faced an investment project with three scenarios (worst-case, base-case, and best-case), for which they were informed about the size of the initial investment and the time with income from the investment. For each of the three scenarios, participants were informed about four key performance indicators: *(i)* the likelihood of the scenario, *(ii)* the net loss or gain from the investment, *(iii)* the yearly internal rate of return (IRR), and *(iv)* the number of years to break-even (B/E). Each participant received information about the same variables but with randomly drawn values (within a prespecified range), giving rise to researcher-controlled variation in explanatory variables. Table 1 summarizes the parametrization used in the online experiment. The choice of key performance indicators and their parametrization was based on the following considerations: *(i)* we consulted standard corporate finance textbooks (such as, e.g., Brealey et al., 2007; Berk and DeMarzo, 2019) and important research contributions (e.g., March and Shapira, 1987; Sitkin and Pablo, 1992; Sanders and Hambrick, 2007) to identify key performance indicators; *(ii)* we conducted interviews with managers of SMEs investigating which indicators they were relaying on when making investment decisions, whether they were aware of standard indicators (such as the net present value and the internal rate of return), and what they would perceive as likely estimates; *(iii)* the estimates of the key characteristics were scaled by a firm size factor—based on the company's gross profits and its total equity, obtained from the company's financial statements—to ensure that the investment project is at reasonable stakes; *(iv)* we tested the final parametrization on research fellows as well as managers of SMEs. Despite these considerations, we acknowledge that the choice of key performance indicators and their parametrization may be arbitrary to some participants. An example of how the parametrization translates into a particular investment opportunity faced by a random participant in the sample is presented in Table A.1 in the Appendix.

Each manager faced a single hypothetical investment opportunity but was shown this opportunity twice: Once to indicate how *risky* they perceive it to be, and once to indicate how *attractive* they perceive it to be. The order of the two questions was randomized to counter potential order effects (see, e.g., Carlsson et al., 2012). On both screens, the information about the business project was preceded by the preamble "Please look at the information below and consider how [risky/attractive] the investment—which is to take place this year—is to your company in its current economic situation". Managers' risk perception was elicited using the question "How risky is this opportunity for your company?" to be answered on a Likert scale ranging from 1 ("not risky at all") to 7 ("very risky"). Managers' perception of the project's attractiveness was elicited using the question "How attractive is this opportunity for your company?" to be answered on a Likert scale ranging from 1 ("not attractive at all") to 7 ("very attractive").

We asked managers to assess the project's attractiveness to proxy investment preferences—instead of asking directly about how likely the company would be to invest in the opportunity—to avoid respondents being inclined to factor in how likely the company would be to face such an opportunity if the likelihood of investing appeared explicitly in the question. Thus, from a methodological point of view, the design of our study joins the rank of a respectable body of literature on perceived risk and perceived benefits (see, e.g., Alhakami and Slovic, 1994; Slovic et al., 2004; Keller et al., 2006; Slovic and Peters, 2006; Holzmeister et al., 2020).

The experiment was part of a larger survey on corporate investment decisions and subsequent management of investments undertaken, which contained a total of 72 questions, with only a small subset of them pertaining to the research questions addressed in this paper. Most of the items were collected to develop a practical online investment management tool, which was requested by the funding body. Apart from the managers' risk perception and investment preferences, the only variable that also enters this study is a proxy for managers' individual-level attitudes toward risk. In particular, we elicited the participants' risk attitudes using the question "Please indicate how willing or unwilling you are personally, in general, to take risks?" to be answered on a Likert scale from 1 ("Completely unwilling to take risk") to 7 ("Very willing to take risk"), introduced by Dohmen et al. (2011).[4] The survey was conducted in Danish.

[3] The survey adheres to and complies with *Danmarks Statistik* 's ethical requirements. This includes (i) preserving participants' anonymity and ensuring confidentiality; (ii) informing respondents about the purpose of the survey and that participation is voluntary; (iii) interviewing 50 managers to ensure that only relevant questions are included, that language is used that can be well understood, and that participants do not feel uncomfortable with answering the survey questions; (iv) offering all participants a report with the main results from the survey; (v) entitling participants to withdraw from the study at any time; and (vi) adhering to legal requirements on data protection.

[4] In addition, we elicited participants' risk preferences using the multiple price list procedure introduced by Holt and Laury (2002). Participants were asked

Table 1
Parametrization of the three scenarios of the investment project presented to participants in the online experiment. All parameters determining the business opportunity's attributes (i.e., s, t, p_i, and r_i)—as defined in the table—were randomly drawn from uniform distributions. The scenarios were scaled by a factor (f), based on the gross return and total equity obtained from the company's accounting data, ensuring that the investment opportunity faced by managers is at reasonable stakes.

	Worst Case (i = 1)	*Base Case (i = 2)*	*Best Case (i = 3)*
Investment size (I)		$I = s \cdot f$ with $s \in \{1\%, 2\%, \ldots, 100\%\}$ and $f = 0.25 \cdot$ gross return + $0.25 \cdot$ total equity	
Time frame (t)		$t \in \{2, 3, \ldots, 10\}$ (indicated as ranges, starting in 2020)	
Likelihood (p_i)	$p_1 \in \{5\%, 10\%, \ldots, 55\%\}$ $(p_1 < p_2)$	$p_2 \in \{40\%, 45\%, \ldots, 70\%\}$ $(p_2 > p1 \wedge p_2 > p_3)$	$p_3 \in \{5\%, 10\%, \ldots, 55\%\}$ $(p_3 < p_2)$
Net loss/gain (π_i)	$\pi_1 = r_1 \cdot I$ with $r_1 \in \{-0.95, -0.90, \ldots, -0.25\}$	$\pi_2 = r_2 \cdot I$ with $r_2 \in \{0.010, 0.011, \ldots, 0.100\}$	$\pi_3 = r_3 \cdot I$ with $r_3 \in \{0.11, 0.12, \ldots, 0.75\}$
Rate of return (irr_i)	$irr_1 \in \{-83\%, -82\%, \ldots, -4\%\}$ (determined by π_1, I, and t)	$irr_2 \in \{3\%, 4\%, \ldots, 20\%\}$ (determined by π_2,I, and t)	$irr_3 \in \{15\%, 16\%, \ldots, 133\%\}$ (determined by π_3, I, and t)
Years to B/E (b_i)	b_1 = *n.a.*	$b_2 \in \{1.5, 1.6, \ldots, 9.1\}$ (determined by π_2, I, and t)	$b_3 \in \{0.6, 0.7, \ldots, 5.4\}$ (determined by π_3, I, and t)

We aimed at inviting the entire population of established SMEs in Denmark to participate in the survey. We thus selected all Danish limited liability companies that were at least five years old, were not holding companies, were not within the financial sector, were not part of a larger group, and had executives who were not involved in other companies (as otherwise, it might introduce confusion about which company their answers should pertain to). This resulted in an eligible sample of 19,759 companies.

The company-specific link to the survey was sent directly to one executive of the 19,759 Danish SMEs. The link was distributed via their personal *e-boks*, a strictly personal government-granted e-mail account, to all individuals in the pool. *Danmarks Statistik* (the Danish governmental statistical bureau) performed the matching of companies and executives as well as the distribution of the survey links to participants. Upon completion of the online survey, the data was merged with information obtained from the financial database *Orbis*, allowing us to control for company size via a company's total assets, shareholder funds (i.e., total equity), gross profits, and the number of employees. For the survey items of relevance to this paper, we received 4287 responses, implying a response rate of 21.7%.[5] Descriptive statistics on the control variables and an analysis of selection effects into the experiment are provided in Appendix B.

3. Results

To investigate which attributes of a business project drive managers' perception of risk and attractiveness, we regress managers' risk and *un*attractiveness[6] judgments on the various project attributes that were exogenously varied in the experiment, controlling for the company's total assets, shareholder funds, gross profit, and number of employees. Fig. 1 shows the (z-standardized) coefficient estimates of ordinary least squares regressions; non-standardized estimates of the same regression models are provided in models (1) and (2) in Table C.1 in the Appendix.

First, we report a positive effect of the size of the required investment on risk perception[7]: On average, an increase by one standard deviation in (the log of) the required investment is associated with an increase of 0.168 standard deviations (se = 0.018, $p < 0.001$) in risk perception. This suggests that managers do not only consider relative measures but also take into account the project's absolute stakes. As such, this result is well in line with the conception of "consequentiality" as put forward by Sanders and Hambrick (2007): The notion of "risk" appears to be associated with the extent to which a company's health and vitality is potentially affected. Likewise, this result integrates well with findings in the literature suggesting that the seriousness of the consequences of a dread event is a key determinant of risk judgments (see, e.g., Yates and Stone, 1992; Sjoberg, 1999, 2000).

The results presented in Fig. 1 also indicate that managers' risk perception is significantly related to the likelihood of the worst-case scenario, which coincides—by the design of the experiment—with the probability of incurring losses. On average, a one-standard-deviation increase in the business opportunity's loss probability increases risk perceptions by 0.138 standard deviations (se = 0.021, $p < 0.001$). Although somewhat smaller in terms of the effect size, we find that the IRR of the worst-case scenario explains a significant share of the variation in managers' risk perception. On average, an increase by one standard deviation in the worst-case IRR (i.e., a less negative outcome) is associated with a decrease in risk perception by 0.082 standard deviations (se = 0.015, $p < 0.001$). In contrast, we do not find evidence for the IRR of both the base-case and the best-case scenario nor the likelihood of the best-case scenario being significantly related to participants' perception of business risk.[8] In line with previous findings (see, e.g., Brachinger and Weber, 1997; Unser, 2000; Veld and Veld-Merkoulova, 2008; Holzmeister et al., 2020;

to indicate whether they prefer a safe lottery (paying DKK 2000 with p and DKK 1600 with $1-p$) or a risky lottery (paying DKK 3850 with p and DKK 100 with $1-p$) for varying probabilities $p \in \{0.10, 0.20, \ldots, 1.00\}$. Risk attitudes elicited using this procedure are used as an alternative to the survey-based proxy of participants' risk preferences in robustness tests.

5 While participants' perception of risk and attractiveness of the business opportunity was elicited at the very beginning of the survey, the question on individual-level risk preferences and the multiple price list (Holt and Laury, 2002) were presented toward the end of the experiment. Since survey items in-between required participants to describe their business activities in an open-ended format, attrition rates were relatively high. A total of 3041 participants completed the self-reported measure on risk preferences; 2537 also completed the multiple price list task.

6 Please note that—for the sake of comparability of effects—we use the reverse-coded survey response on managers' perception of the project's attractiveness as a measure of the project's unattractiveness. Without altering the economic content of the measure, we focus on unattractiveness (instead of attractiveness) judgments as the dependent variable in our analyses to align the signs of effects associated with perceived risk and our proxy of investment propensity.

7 Note that the regression analysis controls for several firm size-related measures, as the effect of absolute measures might be confounded otherwise. In particular, the regression controls for the company's total assets, shareholder funds, gross profit, and number of employees. Since the size of the initial investment is based on a company's total assets and gross profit, the effect is assumed to be properly adjusted.

8 Note that the likelihoods of the best-case, base-case, and worst-case scenarios sum up to 100%. To avoid collinearity and overfitting, the likelihood of the base case scenario thus is omitted in the regression analyses.

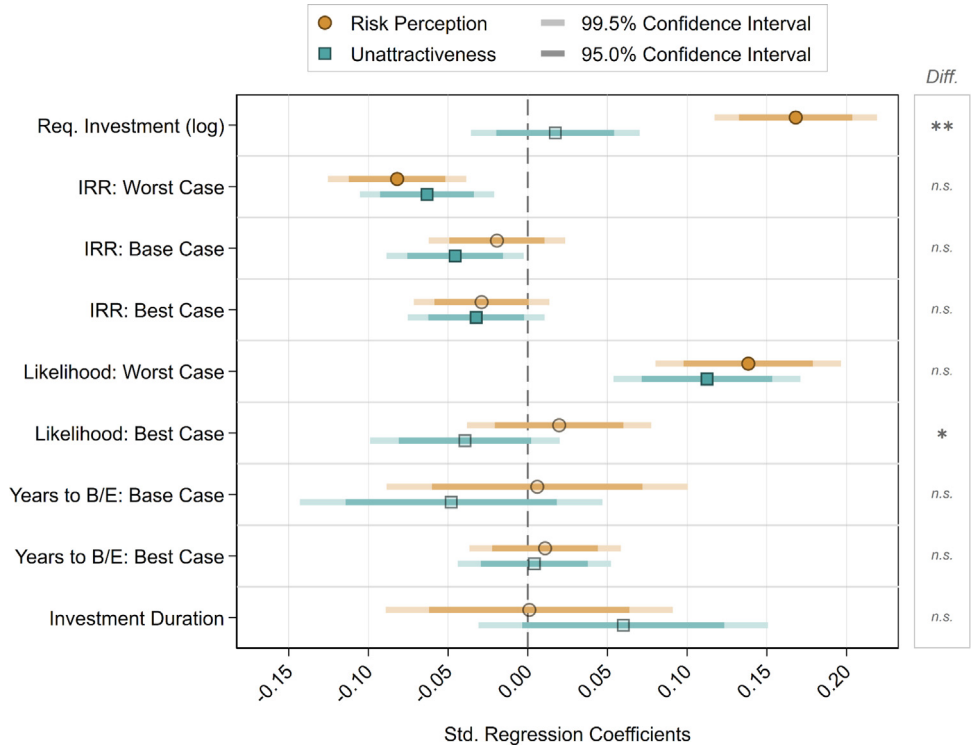

Fig. 1. Effects of business project attributes on managers' risk perception and unattractiveness ratings. The figure shows standardized coefficient estimates based on ordinary least squares regressions of managers' risk perception and unattractiveness ratings on various project attributes (controlling for the company's total assets, shareholder funds, gross profit, and number of employees). Error bars indicate 95% and 99.5% confidence intervals based on robust standard errors. Standardized regression estimates are reported in models (1) and (2) in Table C.1 in the Appendix. The significance indicators on the right refer to differences between coefficient estimates after seemingly unrelated regressions (see footnote 10 for details) as reported in model (3) in Table C.1 in the Appendix; $^{n.s.}$ not significant, * $p < 0.05$, and ** $p < 0.005$.

Zeisberger, 2022b,a), these results indicate that risk perception is primarily driven by downside risk measures. Moreover, we do not find evidence that managers' perception of risk is related to the duration of the project or the years to break-even.

Given these results, the question of whether and to which extent risk perceptions are driven by the interaction of likelihoods and magnitudes of outcomes arises naturally. In a supplementary analysis (reported in Table D.1 in the Appendix), we regress managers' risk perception on the (exogenous) variation in the business opportunity's worst-case outcome (IRR), the probability with which this outcome is expected to be realized (i.e., the loss probability), and the interaction term of the two variables. Corroborating the results reported above, we find a significantly positive simple effect of the likelihood of the worst-case outcome ($b = 0.133$, $se = 0.021$, $p < 0.001$) and a significantly negative simple effect of the worst-case scenario's IRR ($b = -0.079$, $se = 0.015$, $p < 0.001$). Yet, we do not find evidence for the interaction term of the likelihood and the magnitude of losses being statistically different from zero ($b = 0.006$, $se = 0.015$, $p = 0.701$; see model (2) in Table D.1).[9] This result suggests that managers in our sample do not seem to systematically factor in *expected* outcomes, but rather treat likelihoods and outcomes *separately*. These results are in line with previous findings examining drivers of perceived risk in (financial) economic decisions (see, e.g., Holzmeister et al., 2020; Zeisberger, 2022a,b). The lack of a significant interaction effect between likelihoods and the associated monetary outcomes challenges the conceptualization of risk measures based on expectations, such as, e.g., variance, expected loss, or expected shortfall, but also the operationalization of the term "risk" in normative and descriptive expectation-based theoretical models of decision-making under risk, such as, e.g., (subjective) expected utility theory (von Neumann and Morgenstern, 1944; Savage, 1954) or (cumulative) prospect theory (Kahneman and Tversky, 1979; Tversky and Kahneman, 1992).

Turning to the ratings of a project's attractiveness – our proxy for managers' propensity to invest into the business opportunity –, we find that attractiveness judgments negatively correlate with risk perception (Spearman rank correlation: $\rho_S = -0.159$, $p < 0.001$; $n = 4287$). The inverse relationship between perceived risk and perceived attractiveness has been documented for various decision contexts (see, e.g., Fischhoff et al., 1978; Slovic et al., 1991; Weber et al., 1992 for early empirical reports). Alhakami and Slovic (1994) argue that the inverse relationship between perceived risk and perceived benefit is due to a confounding of risk and benefit in people's minds, which might be an "interesting manifestation" of the halo effect (Thorndike, 1920): Human judgments tend to be governed by their perceptions and impressions of general aspects—i.e., characteristics are considered representative whereas other facets, which are considered secondary, are eclipsed. Relatedly, it has been proposed that the inverse relationship between perceived risk and perceived benefit occurs due to people relying on affect and availability (see, e.g., Finucane et al., 2000; Slovic et al., 2004; Keller et al., 2006; Slovic and Peters, 2006). Weber et al. (1992) test various conceptualizations of the potential relationship between risk and attractiveness assessments. Their findings tend to rule out the common mediator hypothesis; rather, their results support the notion of risk and benefits being distinct accessible psychological constructs. Yet,

[9] Likewise, we do not find any evidence for significant interaction effects of likelihoods and magnitudes of both the base-case and the best-case outcomes. Moreover, the significant simple effects of the downside measure (i.e., likelihood and IRR of the worst-case outcome) turn out to be robust when considering the base-case or best-case measures at the same time; for details, refer to Table D.1 in the Appendix.

perceived attractiveness may well be interrelated with perceived risk, and various moderators may influence both constructs. The significant but relatively small correlation between perceived risk and perceived attractiveness in our data integrates well with Weber et al.'s account.

Although assessments of risk and unattractiveness are correlated, the impact of the project attributes turns out not to coincide for the two dependent variables. For the subsequent discussion, we again refer to Fig. 1 (and Table C.1 in the Appendix). First, we do not find evidence for managers' assessment of unattractiveness being systematically affected by (the log of) the required investment (b = 0.017, se = 0.019, p = 0.360); the coefficient estimate for the required investment turns out to be significantly larger for risk perception as compared to unattractiveness judgments (Δ = 0.151, se = 0.024, $p < 0.001$).[10] Second, we report that the impact of downside measures on unattractiveness ratings is comparable to the effect on risk perception (likelihood of the worst-case scenario: b = 0.112, se = 0.021, $p < 0.001$; IRR of the worst-case scenario: b = –0.063, se = 0.015, $p < 0.001$).

While, as compared to the effects on risk perception, the effect of these two downside measures tends to be slightly less pronounced, the coefficient estimates do not significantly differ between the two models (see Table C.1 for details). However, unlike managers' risk perception, their assessments of unattractiveness are also significantly driven by the project's upside potential. In particular, we report negative effects for the IRR of both the base-case (b = –0.046, se = 0.015, p = 0.003) and the best-case scenario (b = –0.032, se = 0.015, p = 0.035); the effect of the likelihood of the best-case scenario turns out to be negative but does not significantly differ from zero (b = –0.039, se = 0.021, p = 0.063).[11] Although the effects of base-case and best-case measures suggest that the extent to which a project is deemed attractive does not only depend on the potential downsides, the coefficient estimates for unattractiveness ratings do not differ significantly from the corresponding estimates pertaining to risk perception (see Table C.1 for details). Overall, our results appear to be in line with pioneering findings by Slovic (1967), Slovic and Lichtenstein (1968), and Lichtenstein and Slovic (1971), arguing that perceived risk and perceived benefits are shaped by people's beliefs about the relative importance of probabilities and outcomes, and their inability to translate these beliefs into judgments when processing information. The results of these early contributions suggest that people's conception of risk is predominantly determined by a prospect's downside probability whereas attractiveness judgments are affected by upside potentials.

While the relationship between perceived risk and perceived benefits has been addressed repeatedly in the literature, the question of whether and to what extent *risk preferences* impact the relationship has rarely been considered.[12] We contribute to the literature by investigating empirically how perceived risk and individual-level risk preferences[13] translate into managers' investment preferences (proxied by their judgments of the project's attractiveness). Relating to this conceptualization of risk and attractiveness (Sitkin and Weingart, 1995; Nosić and Weber, 2010), we first report that unattractiveness ratings are significantly negatively affected by managers' individual-level risk preferences (b = –0.263, se = 0.023, $p < 0.001$; see model (1) in Table C.2 in the Appendix). Although one might be inclined to hypothesize that risk perceptions are interrelated with risk preferences, managers' perception of risk turns out not to be significantly related to their individual-level risk preferences (Spearman rank correlation: ρ_S = –0.000, p = 0.979; n = 3041).

Yet, the question of whether attractiveness perceptions are affected by the interaction effect of risk perception and risk preferences arises. To address this question, we regress managers' unattractiveness judgments on their risk perception, their self-reported risk preferences, and the interaction term of these two factors. Fig. 2 depicts the predictive margins of managers' assessment of the project's unattractiveness (based on a linear regression model; see model (2) in Table C.2 in the Appendix) subject to the (endogenous) variation in perceived risk associated with the project (vertical axis) and individual-level risk preferences (horizontal axis). Strikingly, Fig. 2 shows that the contour levels of the predictions are concave, indicating that managers' ratings of a project's unattractiveness is governed by a significant interaction effect between risk perceptions and individual-level risk preferences (b = 0.047, se = 0.013, $p < 0.001$; see model (2) in Table C.2).[14] Our results suggest that the less risk tolerant a manager is *and* the more risky she perceives the project to be, the more unattractive the project is perceived to be. This effect gives rise to the following observation: On average, highly risk-averse managers tend to perceive the project as relatively unattractive *per se*, irrespective of the extent to which the project is perceived to be risky. Likewise, whenever a project is perceived to be very risky, it is deemed relatively unattractive, with only a small moderating effect of the manager's individual-level risk preferences on attractiveness judgments. We deem this result particularly relevant, as it suggests that managerial decision-making processes are not only affected by subjective conceptions of objective attributes of business opportunities but are also governed by a manager's individual-level *risk preferences*.

[10] We use a seemingly unrelated regression equations model (Zellner, 1962) to test for differences in coefficient estimates (Δ) between the two regressions (see Fig. 1 and Table C.1) to assess whether the effect of particular project attributes is systematically stronger for either of the two dependent measures of interest while accounting for potential correlations in error terms. Both regression equations are valid linear models on their own and can be estimated separately, but the error terms can be assumed to be correlated across the system of equations (which is why the equation system is referred to as "seemingly unrelated"). Since the set of regressors is identical in both regressions, estimates from a seemingly unrelated regression will be numerically identical to the estimates from an ordinary least squares regression (see, e.g., Davidson and MacKinnon, 1993), i.e., taking into account correlated errors only pertains to the tests of differences in coefficient estimates between the two models.

[11] As for the analysis of drivers of risk perception, we conduct supplementary analyses to examine potential interaction effects of likelihoods and magnitudes of outcomes associated with the three scenarios to infer effects pointing toward expectation-based risk and attractiveness assessments. We do not find any interaction effects between likelihoods and magnitudes of returns associated with any of the three scenarios, while the simple effects of the respective measures turn out to be robust. The corresponding analyses are summarized in Table D.1 in the Appendix.

[12] The paper by Nosić and Weber (2010) is one of the few but notable exceptions. The authors propose a model in which choice behavior under risk is governed by perceived returns (i.e., benefits), perceived risk, and individual-level risk preferences. They further show that – in a financial context – subjective measures of risk and benefits, i.e., risk and return perceptions, are better proxies for risk-taking behavior than objective risk measures. Following the theoretical emphasis put forth by Sitkin and Pablo (1992), Sitkin and Weingart (1995) model risk-taking behavior as being determined by risk propensity (i.e., risk preferences), risk perception, and a mediating effect of risk propensity on risk perception.

[13] Please note that we follow the tradition in the economics literature in this regard, i.e., we consider risk preferences to be distinct from risk perceptions. In particular, we treat risk preferences in the sense of a latent trait (see, e.g., Frey et al., 2017), characterizing to which extent a decision-maker is willing to engage in risk-taking behavior *per se* . Yet, it appears intuitively evident that risk preferences are likely to be interrelated with risk perceptions: we hypothesize that more (less) risk-tolerant managers would be less (more) likely to be scared off by opportunities that are *perceived* to be risky.

[14] Notably, these effects turn out to be qualitatively robust if we replace the self-reported measure of risk preferences with the number of risky choices participants made in the multiple price list (Holt and Laury, 2002). In particular, we find a significant interaction effect of revealed risk preferences elicited using the price list setting and managers' perception of risk (b = 0.035, se = 0.009, p < 0.001) and a significant simple effect of the number of risky choices (b = –0.212, se = 0.042, p < 0.001) on manager's unattractiveness ratings. Please refer to Table C.2 in the Appendix for details.

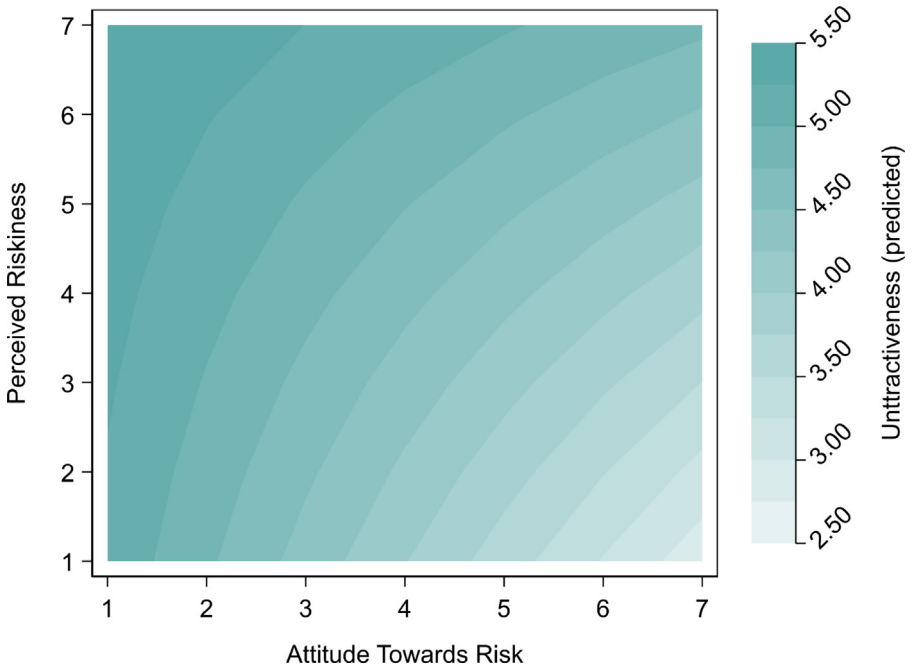

Fig. 2. Contour plot of predictive margins of managers' unattractiveness ratings conditional on their individual-level attitudes toward risk and the perception of risk. Estimates (unstandardized) are based on ordinary least squares regressions of managers' perceived unattractiveness on perceived riskiness, their individual-level risk preferences, and the interaction term thereof. The corresponding regression estimates are provided in model (2) in Table C.2 in the Appendix.

4. Discussion and conclusion

This study contributes to the research area of studies examining behavioral aspects of managerial decision-making, initiated by March and Shapira (1987). Using an experimental research design that allows for a systematic delineation of which aspects of the construct "risk" best predict managers' engagement in managerial risk-taking, our study consolidates and advances the literature by providing a more comprehensive understanding of how managers perceive risk and attractiveness in a business context. As such, we contribute to the literature on decision-making under risk more generally, providing experimental evidence on the interrelations between judgments of risks and benefits of a large sample of business executives.

Our findings suggest that the processes that result in managers' judgments of a business project's risk and attractiveness are somewhat detached from the classical processes of choosing among alternative actions based on evaluating the trade-off between the mean (expected value) and the variance (risk) of the probability distributions over possible outcomes, supporting earlier results on a "description-perception" gap (see, e.g., Holzmeister et al., 2020). We find that managers' conception of risk is governed by the potential downsides associated with a project, but not its upsides. Both higher likelihoods and higher magnitudes of the worst-case outcome induce managers to perceive business opportunities as being more risky. The impact of the likelihood of the worst-case outcome on managers' risk perception is noteworthy, as previous studies provide mixed evidence on likelihood as a risk measure. On the one hand, there have been indications that individuals do not trust, do not understand, or simply do not use likelihood estimates when assessing risk (see, e.g., Slovic, 1967; Fischhoff et al., 1978; MacCrimmon et al., 1986; Shapira, 1986). On the other hand, more recent findings suggest that likelihood estimates – particularly the probability of incurring losses – strongly affect decision-makers' perception of risk (see, e.g., Holzmeister et al., 2020; Zeisberger, 2022b,a). Moreover, we do not find evidence for the interaction of likelihoods and magnitudes being systematically related to risk perception, suggesting that the likelihoods and outcomes enter managers' perception of risk independently, rather than as their products (Slovic, 1987; Holzmeister et al., 2020).

Furthermore, we find that managers' risk perception increases with the size of the required investment, indicating that managers also integrate the business opportunity's absolute stake into their risk assessment. Notably, most of the previous literature in the realm of managerial decision-making either omit consequential outcomes in conceptualizing risk-taking (e.g., Sitkin and Pablo, 1992) or treat it as a relatively complete indicator of risk-taking (e.g., Sjoberg, 2000; Sanders and Hambrick, 2007). Our result challenges both types of conceptualizations and suggests that the consequentiality of results partly explains what is perceived as risky.

Turning to investment preferences, we find that managers' perception of attractiveness is inversely related to their risk perception. This suggests that risk and benefits associated with a business project are negatively correlated in managers' minds and assessments, which is in support of several empirical reports of an inverse relationship between perceived risk and perceived benefits (see, e.g., Weber et al., 1992; Alhakami and Slovic, 1994; Holzmeister et al., 2020). When assessing the attractiveness of the project, managers do not only rely on returns and likelihoods of the worst-case scenario but also the returns of the base-case and best-case outcomes. Again, our results appear to integrate well with early contributions to the literature (see, e.g., Slovic and Lichtenstein, 1968; Lichtenstein and Slovic, 1971), arguing that risk and attractiveness judgments are determined by the decision maker's belief about the relative importance of likelihoods and outcomes: Individuals tend to associate "risk" with potential downsides, whereas perceived attractiveness tends to be governed by a prospect's upside potential.

Furthermore, we provide novel empirical insights into the interrelation of individual-level risk preferences and risk perceptions as well as their interaction effect on the judgment of

attractiveness(see, e.g., Sitkin and Weingart, 1995). Our results suggest that highly risk-averse managers perceive investment opportunities to be relatively unattractive, irrespective of whether or not it is perceived to be risky; by contrast, whenever an investment opportunity is perceived to be highly risky, judgments of attractiveness turn out to be low, irrespective of the manager's risk preference. The latter result suggests that the considerable underweight of research not taking into consideration the heterogeneity in risk preferences in investigations of the relationship between perceived risk and perceived benefits isunmerited. As called for by Holzmeister et al. (2022), an encompassing model of the risk construct – integrating both risk perceptions *and* risk preferences – appears to be a promising avenue for future research to further advance our understanding of decision-making under risk as well as to improve the predictive validity and practical applicability of our models.

A natural follow-up question to the research questions addressed in this paper is whether the identified effects are mediated and/or moderated by individual-level characteristics of the manager (and/or various firm-level attributes). Indeed, several individual-level characteristics of the manager (and/or various firm-level characteristics) have been demonstrated to affect managerial decision-making and risk-taking (see, e.g., MacCrimmon and Wehrung, 1990; Nicholson et al., 2005; Martino et al., 2020; Pelster et al., 2023). We deem it important to provide unconditional evidence as a first step and leave it to future research to systematically examine potential moderator and/or mediator effects of individual (and/or firm-level) characteristics. Importantly, however, all attributes of the business projects evaluated by the managers in our experiment have been randomly assigned (and firm-level characteristics that enter the construction of the project attributes are controlled for). Consequently, individual-level characteristics are orthogonal to the project-level characteristics that enter our analyses as independent variables, such that our results can be interpreted as unbiased average effects pertaining to the two research questions addressed in this paper.

Our results have important implications for how we understand managerial decision-making. Particularly, there seems to be a gap between how we conceive (and model) the assessment of risky prospects and how managers assess business opportunities. In general, managers seem to rely on simpler measures than those suggested by decision theory, which typically relies on variance as a measure of risk. Our finding that managers do not seem to perceive variance as the defining moment of risk, but rather rely on isolated moments of the outcome distribution, suggests that managerial perspectives could be challenged through direct training in decision-theoretic approaches to the assessment of business opportunities. Whether the heuristics involved in managerial decision-making could be overruled by multi-faceted prospect evaluations through dedicated training is an open question. Yet, our paper has the potential to aid the conversation between business managers and academically trained financial practitioners (loan officers, investors, etc.) by making them aware that the normative perspective on risk is not (necessarily) shared by managers. Risk communication could be facilitated by explicating the "description-perception" gap (see, e.g., Holzmeister et al., 2022), referring to what exactly makes a business opportunity risky from the viewpoint of the manager, and emphasizing the discrepancy between normative and positive decision-making models.

The indication that managers tend to deviate from decision-theoretic approaches when evaluating risks and benefits associated with business opportunities raises the question of whether managers are prone to make suboptimal decisions *per se*. In other words, would managers make better decisions if they followed the procedures put forward by standard decision theory, as compared to basing their judgments on affective measures and heuristics? Are certain types of decision-making environments or contexts more suitable for relying on heuristics? Do individual-level risk preferences moderate the likelihood of making subpar decisions? Does the level of diversification affect business managers' risk perception? Answering these and related questions seems to promise valuable insights not only for academics but also for managers, and, thus, appears to be a fruitful avenue for future research.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Details on the experiment

See Table A.1.

Appendix B. Recruitment and register data

See Table B.1.

Appendix C. Supplementary tables

See Tables C.1 and C.2.

Appendix D. Supplementary analyses

See Table D.1.

Table A.1
Example of a hypothetical investment opportunity as shown to survey participants. For a detailed description of the parametrization and range of the various attributes, please refer to the description in the main text. The *yearly returns* (IRRs) presented to the participants were based on the assumption that the initial cash outflow (*size of initial investment*) took place in 2019 (at the time of the survey) while cash inflows–the *size of initial investment* (recouped) + *Net loss (−) or gain (+)*–were evenly spread out over the *time period with income from the investment*. Thus, for instance, the base case IRR below results from the following cash flows t_0 = −13,000,000, t_{1-3} = (13,000,000 + 4,300,000) ÷ 3. The information about the underlying IRR assumptions was not presented to respondents as it was deemed sufficiently complex to divert their focus from the task at hand.

	Worst Case	*Base Case*	*Best Case*
Size of initial investment	DKK 13,000,000	DKK 13,000,000	DKK 13,000,000
Net loss (-) or gain (+) from the investment	DKK −3,900,000	DKK 4,300,000	DKK 21,000,000
Yearly return (IRR)	−16%	16%	69%
Time period with income from the investment	2020–2022	2020–2022	2020–2022
Number of years until break-even	*n.a.*	2.3	1.1
Likelihood of scenario	10%	70%	20%

Table B.1
Descriptive statistics on firm-specific covariates used as control variables in all analyses, separated for experimental participants (Respondents) and managers in the population who did not participate in the study (Non-Respondents). Total assets, shareholder funds (i.e., total equity), and gross profits are measured in DKK 1,000,000. Means and standard deviations (SD) as well as medians and inter-quartile ranges (IQR) are provided. The right-most column indicates the results of two-sample *t*-tests using Welch's approximation to adjust for unequal variances.

	Respondents		Non-Respondents		
	Mean (SD)	*Median (IQR)*	*Mean (SD)*	*Median (IQR)*	*t-Statistic (p-value)*
Total assets	24.11 (45.77)	8.39 (18.34)	20.01 (40.67)	6.96 (14.25)	5.305 (< 0.001)
Shareholder funds	9.49 (21.78)	2.97 (6.79)	7.61 (21.91)	2.33 (5.56)	5.000 (< 0.001)
Gross profits	13.33 (21.29)	6.39 (10.45)	11.05 (18.63)	5.39 (8.03)	6.359 (< 0.001)
Number of employees	22.93 (32.65)	12.00 (17.00)	19.54 (28.40)	10.00 (13.00)	6.175 (< 0.001)
Observations	4287		15,472		

Table C.1
Regression analyses of perceived riskiness (1) and perceived unattractiveness (2) on the various attributes of the business project varied in the experiment. Estimates (standardized) are based on ordinary least squares regressions. *Controls* include the company's total assets, shareholder funds (i.e., total equity), gross profits, and the number of employees. Model (3) reports the differences between models (1) and (2) as based on seemingly unrelated regressions (see footnote 10 for details). Robust standard errors are provided in parentheses.

	(1) Perceived Riskiness	(2) Perceived Unattract.	(3) Difference (1)–(2)
Req. Investment (log)	0.168** (0.018)	0.017 (0.019)	0.151** (0.024)
IRR: Worst Case	−0.082** (0.015)	−0.063** (0.015)	−0.019 (0.020)
IRR: Base Case	−0.019 (0.015)	−0.046** (0.015)	0.026 (0.021)
IRR: Best Case	−0.029 (0.015)	−0.032* (0.015)	0.003 (0.020)
Likelihood: Worst Case	0.138** (0.021)	0.112** (0.021)	0.026 (0.028)
Likelihood: Best Case	0.020 (0.021)	−0.039 (0.021)	0.059* (0.027)
Years to B/E: Base Case	0.006 (0.034)	−0.048 (0.034)	0.054 (0.044)
Years to B/E: Best Case	0.011 (0.017)	0.004 (0.017)	0.007 (0.022)
Investment Duration	0.001 (0.032)	0.060 (0.032)	−0.059 (0.043)
Constant	0.007 (0.020)	0.035 (0.020)	
Controls	*yes*	*yes*	
Observations	4287	4287	
Adjusted R^2	0.044	0.027	

* $p < 0.05$
** $p < 0.005$

Table C.2
Regression analyses of managers' assessment of project attractiveness on perceived risk, individual-level risk preferences, and the interaction term thereof. Estimates (non-standardized) are based on ordinary least squares regressions. Models (1) and (2) pertain to self-reported risk preferences elicited using the survey item proposed by Dohmen et al. (2011); models (3) and (4) pertain to the elicited risk preferences using a multiple price list format (Holt and Laury, 2002). *Controls* include the company's total assets, shareholder funds (i.e., total equity), gross profits, and the number of employees. Robust standard errors are provided in parentheses.

	(1) Perceived Unattract.	(2) Perceived Unattract.	(3) Perceived Unattract.	(4) Perceived Unattract.
Perceived Riskiness	0.191**	0.002	0.270**	0.122*
	(0.021)	(0.053)	(0.024)	(0.045)
Attitude Toward Risk	−0.263**	−0.437**		
	(0.023)	(0.058)		
Perceived Riskiness # Attitude Toward Risk		0.047**		
		(0.013)		
Attitude Toward Risk (Holt & Laury)			−0.078**	−0.212**
			(0.013)	(0.042)
Perceived Riskiness # Attitude Toward Risk (Holt & Laury)				0.035**
				(0.009)
Constant	4.916**	5.607**	3.705**	4.263**
	(0.138)	(0.237)	(0.128)	(0.203)
Controls	*yes*	*yes*	*yes*	*yes*
Observations	3041	3041	2537	2537
Adjusted R^2	0.077	0.083	0.077	0.085

* $p < 0.05$
** $p < 0.005$

Table D.1
Regression analyses of perceived risk (models (1) and (2), respectively) and perceived unattractiveness (models (3) and (4), respectively) on the likelihood of the scenarios, the internal rate of return (IRR), and their interaction terms. Estimates (standardized) are based on ordinary least squares regressions. *Controls* include the company's total assets, shareholder funds (i.e., total equity), gross profits, and the number of employees. Robust standard errors are provided in parentheses.

	(1) Perceived Riskiness	(2) Perceived Riskiness	(3) Perceived Unattract.	(4) Perceived Unattract.
IRR: Worst Case	−0.075**	−0.079**	−0.057**	−0.061**
	(0.015)	(0.015)	(0.015)	(0.015)
Likelihood: Worst Case	0.115**	0.133**	0.151**	0.110**
	(0.016)	(0.021)	(0.016)	(0.021)
IRR: Worst Case # Likelihood: Worst Case	0.005	0.006	0.007	0.007
	(0.015)	(0.015)	(0.015)	(0.015)
IRR: Base Case	0.004		0.070	
	(0.083)		(0.083)	
Likelihood: Base Case	−0.139		0.302	
	(0.162)		(0.162)	
IRR: Base Case # Likelihood: Base Case	−0.045		−0.217	
	(0.149)		(0.149)	
IRR: Best Case		−0.029		−0.036*
		(0.015)		(0.015)
Likelihood: Best Case		0.018		−0.041
		0.021		0.021
IRR: Best Case # Likelihood: Best Case		−0.004		−0.011
		(0.015)		(0.015)
Constant	0.018	−0.058**	−0.139	0.029
	(0.091)	(0.019)	(0.091)	(0.019)

(*continued on next page*)

Table D.1 (*continued*).

	(1) Perceived Riskiness	(2) Perceived Riskiness	(3) Perceived Unattract.	(4) Perceived Unattract.
Controls	*yes*	*yes*	*yes*	*yes*
Observations	4287	4287	4287	4287
Adjusted R^2	0.026	0.026	0.026	0.024

* $p < 0.05$
** $p < 0.005$

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