Overconfidence, Effort, and Investment

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Abstract

A positive relation between confidence and effort/investment provision has been theoretically justified and practically assumed in the literature, but has not been thoroughly investigated. We test and confirm this positive relation between direct measures of confidence and choice of effort or investment. More precisely, strong overconfidence results in excess investment of effort and money, underconfidence induces insufficient effort provision and underinvestment, and moderate overconfidence leads to accurate decisions. Our experimental results can be generalized as they are based on different subject pools (financial professionals and students), media (computer-, paper-, and web-based), and types of effort (real mental effort and monetary effort, i.e. investment).

Keywords: Self-confidence, Overconfidence, Judgmental Bias, Overinvestment, Investment Choice, Effort

JEL Classifications: G11, J22

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A positive relation between confidence and effort/investment provision has been theoretically justified and practically assumed in the literature, but has not been thoroughly investigated. We test and confirm this positive relation between direct measures of confidence and choice of effort or investment. More precisely, strong overconfidence results in excess investment of effort and money, underconfidence induces insufficient effort provision and underinvestment, and moderate overconfidence leads to accurate decisions. Our experimental results can be generalized as they are based on different subject pools (financial professionals and students), media (computer-, paper-, and web-based), and types of effort (real mental effort and monetary effort, i.e. investment).

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Self-confidence or believing in one's own abilities is celebrated as a prerequisite for success. Society has always been emphasizing national and individual self-confidence in many ways: from a temperate Henry Ford's "Whether you think you can or think you can't – you are right" to a more spirited "Yes, we can!" used by Barack Obama in his presidential campaign in 2008. Self-confidence keeps a person happier and more satisfied with her life; it helps to pursuade potential employees, business partners, or life companions that this person possesses positive characteristics and high abilities (Reuben et al. 2012). Moreover, self-confidence boosts motivation to undertake new projects or continue old ones in the face of obstacles, failures, or lack of willpower (Benabou and Tirole 2002). However, one can also be too self-confident and many negative effects of overconfidence have been proposed in the literature.[2] It is conceivable that the beneficial effects of self-confidence can be traded off against the detrimental ones, such that confidence levels are kept at optimum levels.

In this study, we investigate the potentially beneficial effects of moderate overconfidence on effort provision and investments. Our experimental design enables us not only to measure directly individuals' confidence (and overconfidence) in their abilities in a specific domain, but also to assess separately their abilities in the same domain (in our case, financial knowledge). We define confidence as a person's belief about her competence in the financial domain, and overconfidence as a positive difference between that belief and her actual competence. Note that although most people generally tend to be overconfident, our definition also allows for underconfidence: when people's beliefs about their skill level are lower than their actual skill level.

We measure overconfidence in two different ways: *overestimation* (or *optimism*, when subjects estimate their ability, achievements, level of control, or probability of success to be higher than they actually are; see Moore and Healy 2008) and *better-than-average* (aka *overplacement*, when subjects believe themselves to be better than others). We do not consider *overprecision* (when subjects express excess certainty in their beliefs and give too narrow intervals for possible realizations of future events). Overprecision refers to a tendency to

[2] See for example, studies by Barber and Odean (2001), Fenton-O'Creevy et al. (2003), Malmendier and Tate (2005a, 2005b), Malmendier and Tate (2008), Liu and Taffler (2008), Aktas et al. (2012), Deshmukh, Goel, and Howe (2013), Schrand and Zechman (2012), Hribar and Yang (2011).

underestimate the variability of phenomena (e.g., volatility of future market returns), whereas overestimation and overplacement refer to an inclination to overestimate levels of phenomena (e.g. the number of correct answers a person gives in a quiz or future market index returns) either in comparison with actual levels or in comparison with the levels of others.

We contribute to the overconfidence literature in the following ways. First, following Malmendier and Tate (2005a, 2005b), many studies in the finance literature use personal managerial investments, specifically stock-option holdings, as a proxy for managerial confidence. This measure is likely to reflect a mixture of different manifestations of overconfidence, such as overestimation, overprecision, and illusion of control. In our experiment, we are able to separate those measures and we use *overestimation* and *better-than-average*. Moreover, a positive relation between overestimation and chosen investment has not been thoroughly investigated and corroborated in the empirical literature. The impact of accurate confidence or being underconfident on effort and investment provision has received even less attention. We confirm that there is a positive relation between overestimation and better-than-average, on the one hand, and choice of effort level (in a real-effort task) and investment choice (monetary effort) on the other hand. Moreover, strong overestimation leads to both excessive effort and investment levels chosen by subjects, whereas underestimation is related to underprovision of effort and investment. Only the subjects with moderate levels of overconfidence are well-calibrated in terms of their decisions and choose accurate effort and investment levels.

The lack of empirical corroboration in the literature of a relation between confidence and effort can be explained by practical difficulties in distinguishing between confidence and actual ability, and in finding adequate measures for effort. Moreover, without a proper reference point (a person's actual ability), it is impossible to identify whether that person overestimates or underestimates her skill in a specific domain. For example, Ben-David, Graham, and Harvey (2013) use forecasts of S&P500 made by financial professionals and compare those forecasts with historical and realized S&P500 performance to obtain measures for professionals' optimism and miscalibration. Still, those measures are unrelated to individuals' beliefs about their own ability. Thus, our second contribution consists of the fact that our experimental design enables us to measure an individual's skill separately from her confidence in her skill, which allows us to pinpoint underconfidence as well as moderate and strong overconfidence.

Third, we show that our results hold for different types of subjects: financial laymen with a bona-fide affinity for finance as indicated by the fact that they are students enrolled in business or economics university programs, and financial professionals proper, such as financial managers, bankers, and financial consultants. Our study is in accordance with the literature showing that professionals and students make decisions along similar lines (Glaser, Langer, and Weber 2007, 2012; Menkhoff, Schmeling, and Schmidt 2013). Fréchette (2011) gives an overview of the differences in professionals' and students' behavior. Professionals are defined as people working in a field closely related to the economic "game" in question. Remarkably, only in 1 study out of 13 under consideration, the behavior of professionals is closer to the theoretical predictions than that of students. In all other cases, the professionals suffer from behavioral biases to the same extent or even more than laymen do.

Finally, we test whether our results differ across media, by performing the experiment on a computer in a lab, on paper in a classroom, and by means of a web-based tool. While lab studies have become the standard, the appropriateness of web-based experiments is still subject to an intense debate[3] (Horton, Rang, and Zechhauser 2011; Chesney, Chuan, and Hoffmann 2009; Gosling et al. 2004; Anderhub, Müller, and Schmidt 2001). We contribute to the above debate by demonstrating that the positive effects of confidence on effort choice can arise irrespective of whether they are assessed in lab-, paper- or web-based situations.

The remainder of the paper proceeds as follows. The next section describes a model which motivates the research question and introduces the empirical predictions. Section 2 details the experimental design. The results are provided in Section 3 and discussed in Section 4, which also describes some caveats of the study. Section 5 concludes.

[3] The results of internet-based experiments are mostly found to be similar to those from lab experiments (see also Amir and Rand 2012; Duersch, Oechssler, and Schipper 2009).

1. Motivating model and empirical predictions

To motivate our empirical predictions, we develop a simple model that provides the intuition on why higher confidence leads to higher effort and why under- and overconfidence may result in under- and overprovision of effort. We consider a one-period managerial utility maximizing problem whereby a manager decides how much effort (investment) to put into a specific project. We assume that the production functions of both effort and investment have decreasing returns to scale. Without loss of generality, we refer to the managerial problem as a choice of effort level rather than choice of investment level.

The manager chooses her optimal effort level e^* in a project, where the project value is defined by manager's production function $p(e,s)$. The production function depends on effort level e and managerial skill level s, with the following properties $p(0,s)=0$, $p_e>0$, $p_{ee}<0$, $p_s>0$, $p_{es}>0$, and $\lim_{e\to 0} p_e(e,s)=+\infty$, which guarantee that a strictly positive effort level is always optimal for any skill level $s>0$.

As the manager does not know her ability s, her optimal choice is determined by her beliefs about her personal skill. To model potential biases in a manager's beliefs, we assume that she perceives her skill level as $\tilde{s}$, where $\tilde{s}=s$ corresponds to unbiased beliefs, $\tilde{s}>s$ corresponds to overconfidence and $\tilde{s}<s$ to underconfidence.

For every effort level e, the manager bears effort cost $c(e)$, and the cost function $c(.)$ has the following properties: $c(0)=0$, $c_e>0$, and $c_{ee}\geq 0$. For simplification, we assume that the manager is risk neutral and receives the total project value as her compensation.[4] The manager's problem is to maximize her utility function given her beliefs about her skill level $\tilde{s}$, and her utility equals the difference between her compensation and her effort cost. Thus, the manager's problem can be written as follows:

$$\max_e\{p(e,\tilde{s})-c(e)\}\ , \qquad (1)$$

with the first order condition of $p_e(e^*,\tilde{s})=c_e(e^*)$. (2)

[4] If the manager is risk-averse, the model's predictions do not change as the manager's problem does not involve any risky decisions. However, two extensions are possible. Output can be a noisy function of manager's effort or the manager can hold probabilistic beliefs about her skill level. In both cases, a risk-averse manager exerts insufficiently low effort, and moderate overconfidence brings her effort choice closer to the optimal level.

Thus, belief $\tilde{s}$ determines a manager's effort choice: a manager with a higher belief $\tilde{s}_h$ chooses a higher effort level than her peer with a lower belief $\tilde{s}_l$, irrespective of the actual skill levels of both managers.

Lemma 1. Consider two managers with the same productivity functions and the same effort cost functions, but different beliefs about their skill levels $\tilde{s}_h$ and $\tilde{s}_l$, where $\tilde{s}_h > \tilde{s}_l$. Then, the manager with the higher belief $\tilde{s}_h$ chooses higher effort level, $e_h^* > e_l^*$.

Proof: Using $e^*(\tilde{s})$ as an implicit function, equation (2) can be rewritten as follows: $p_e(e^*(\tilde{s}), \tilde{s}) = c_e(e^*(\tilde{s}))$. We differentiate the previous equation with respect to $\tilde{s}$ to calculate whether $e^*(\tilde{s})$ increases or decreases in $\tilde{s}$:

$p_{ee}(e^*(\tilde{s}), \tilde{s}) \cdot e_{\tilde{s}}^* + p_{e\tilde{s}}(e^*(\tilde{s}), \tilde{s}) = c_{ee}(e^*(\tilde{s})) \cdot e_{\tilde{s}}^*$.

Or $e_{\tilde{s}}^* = \frac{p_{e\tilde{s}}}{c_{ee} - p_{ee}} > 0$ as $p_{es} > 0$, $c_{ee} \geq 0$ and $p_{ee} < 0$.

So the effort level chosen by a manager increases in her belief $\tilde{s}$ about her skill level and a manager with a higher belief $\tilde{s}_h$ about her skill level would choose a higher effort level $e_h^* > e_l^*$ than her peer with a lower skill estimation, $\tilde{s}_l$. ■

Lemma 1 implies that if a manager's belief does not accurately reflect her actual skill level, $\tilde{s} \neq s$, then her effort choice does not maximize her objective function. Overconfident managers ($\tilde{s}_{oc} > s$) exert excess effort and bear unnecessary costs that decrease their final compensation; whereas underconfident managers $\tilde{s}_{uc} < s$ choose effort levels lower than optimal and suffer from underproduction. Figure 1 illustrates both situations.

[Insert Figure 1 about here]

Our model predicts that the effort level increases in a manager's confidence about her skill and this effect is symmetric for both under- and overconfident managers. Moreover, overconfident managers exercise higher effort and underconfident managers exercise lower effort than would be optimal given their actual skill level. In other words, our model yields the following predictions.

Prediction 1: A manager's higher confidence in her ability leads to higher effort irrespective of her actual skill level.

Prediction 2: The above effect holds for both under- and overconfidence, i.e. underconfidence results in insufficient effort and overconfidence leads to excessive effort.

In our model, an overconfident manager chooses a higher effort level because she believes that a higher skill level makes her effort more productive than it is in reality, and not because she believes that a higher skill level decreases the effort cost.[5] In the experiment, we impose that skill level only increases productivity and does not affect effort costs.

2. Experimental Design

The participants act as managers who choose how much to invest in a project, depending on their skill level and the project characteristics. Each experiment consists of two parts. In Part 1, we assess the subjects' skill and confidence in the finance domain. In Part 2, subjects make incentivized effort provision decisions for several projects, whereby we distinguish between the Investment treatment (effort is exerted in terms of a monetary investment) and the Real-effort treatment (subjects perform a real-effort task). Subjects are not told about their performance in Part 1 so their decisions in Part 2 are based on their beliefs about their skill level. We use their confidence in their financial knowledge in Part 1 as a proxy for their beliefs about their skill level and compare it with the actual or average skill level to obtain overestimation and better-than-average measure. Finally, we relate these measures to effort and investment level choice in Part 2.

2.1 Measures of skill and confidence (Part 1)

The subjects answer 20 financial knowledge questions (see Appendix A) to measure their skill level, which corresponds to the level of their financial knowledge.[6] For each question, the subjects are asked to choose the correct answer from two alternatives. After making their choice for each question, they assign a probability that the choice is correct (between 50% and 100%). A subject's average probability that she has correctly answered the questions corresponds to her subjective confidence in her financial knowledge. We expect that subjects with higher confidence levels will choose higher effort/investment levels in Part 2.

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[5] If skill simultaneously increases productivity and decreases marginal costs of effort, then overconfident individuals should increase their effort even more compared to their unbiased peers.

[6] Among others, our questions include those proposed by Van Rooij, Maarten, Lusardi, and Alessie (2011). We also include three questions from the cognitive reflection task by Frederick (2005).

2.2 Effort/Investment (Part 2)

At the beginning of Part 2, subjects decide on their personal skill level according to Table 1. They are told that their skill level is constant during Part 2 and is defined only by the number of correct answers given in Part 1. Subjects are not told about their performance in Part 1, so they have to form an expectation about the number of correct answers they gave and the resulting skill level.

[Insert Table 1 about here]

After subjects form an expectation about their skill level, they are randomly assigned to either the Investment or the Real-effort treatment. We employ a between-subject experimental design such that each subject participates only in one treatment. In the Investment treatment, subjects decide on an investment level, whereas in the Real-effort treatment they decide how much effort to apply by choosing a difficulty level of the specific task. In both treatments, the resulting performance depends on subject's effort (investment) level and her actual skill, not on her beliefs about her skill level.

2.2.1 Investment treatment

To insure that all subjects face an identical cost function, we proxy effort costs by monetary expenditures, which is in line with a long-standing experimental tradition.[7] In the experimental task, subjects choose an investment level to maximize their earnings in different projects (see below). In each project, subjects' earnings are equal to the realized revenues plus an initial endowment of 500 cent[8] minus the cost of investment. The cost of investment depends only on the chosen investment level and grows from 60 cent for investment level 1 up to 500 cent for investment level 5 (see the last column of Table 2, all Panels).

[Insert Table 2 about here]

Basic Project

In the Basic Project[9], the cost function and the revenue function for each skill level are discrete approximations of the cost and production functions discussed in

[7] See for example Fehr, Kirchsteiger, and Riedl (1993), Charness (2000), Fehr, Fischbacher, and Gächter (2002), Hannan, Kagel, and Moser (2002), Maximiano, Sloof, and Sonnemans (2007), Schmelz and Ziegelmeyer (2011), and Maas, Rinsum, and Towry (2012).

[8] 1 Euro was about $1.32 at the time of the experiment.

[9] In the experiment, projects are referred to using ordinal numbers to avoid any framing effects.

the model Section 2. For each skill level, the revenue function is concave and the cost function is convex in investment level (see Table 2, Panel A).

Without loss of generality and to guarantee a unique optimal investment level for each skill level, the revenue function is constructed in a way that earnings (revenues plus endowment minus cost of investment) are the highest only when the chosen investment level equals a subject's actual skill level. Both under- and overestimation of skill lead to suboptimal investment choices. So, in order to maximize their earnings, subjects with skill level 1 should choose investment level 1, subjects with skill level 2 should choose investment level 2, etc.

Strong Incentives Project

Whereas the Basic Project has realistic productivity and cost functions, it may fail to provide subjects with sufficiently strong incentives to form unbiased beliefs about their personal skill level. Consider a subject with skill level 3. If she estimates her skill level correctly, she chooses investment level 3 and receives 1130 cent.[10] If she believes that her skill level is 4 and wrongly chooses investment level 4, she receives 1060 cent in earnings. Thus, by being overconfident and by choosing excessively high investment level, the subject loses only 70 cent. If, in addition, she extracts some positive utility from thinking that her ability (in this case, financial knowledge) is higher than it is in reality, then it is conceivable that the incentives in the Basic Project are not strong enough to ensure unbiased skill assessment.

To provide subjects with stronger incentives, we introduce another project, which is called the Strong Incentives Project (see Table 2, Panel B). In this project, subjects' revenues are positive only when they correctly choose an investment level equal to their actual skill level, and zero otherwise.[11] The subjects still bear the costs of the chosen investment, which are independent of the realized revenues and are the same as in the Basic Project.

Loss Aversion Control Project

If subjects are loss averse and set a reference point at their initial endowment of 500 cent then, while making their investment choice in the Strong Incentives

[10] Earnings equal revenues plus endowment minus cost of investment. When skill level is 3 and chosen investment level is 3, earnings are 850 + 500 - 220 = 1130 cent.

[11] In other words, it is not possible to achieve higher revenues by choosing a higher investment level as it was in the Basic Project. So in the Strong Incentives Project, it is not possible to substitute skill with investment/effort.

Project, they may become more conservative in their skill level estimation and may even become underconfident. Consider the following example. A subject believes that her skill level equals 4 with probability $p > \frac{1}{2}$ and 3 with probability $1 - p$. If she chooses investment level 4, then with probability $1 - p$ she incurs a loss of 340 cent and if she chooses investment level 3, then with probability p she loses only 220 cent. If the subject is loss averse, then she may choose investment level 3 even if she assigns a higher probability to skill level 4. To insure that subjects' choices are not affected by their loss aversion, we introduce the Loss Aversion Control Project (see Table 2, Panel C).

The Loss Aversion Control Project provides subjects with identical incentives to estimate their skill level correctly irrespective of their actual or believed skill level and of their loss aversion. In this project, the costs of every investment level are the same and equal 220 cent. Thus, if a subject chooses the investment level corresponding to her actual skill level, then she receives 1130 cent in earnings; otherwise she receives zero.

Risky Project

In reality, the investment output is often affected by random shocks that do not depend on a manager's skill or investment and cannot be predicted. To explore whether risk changes subjects' choice of investment level, we set up the Risky Project, in which revenues are subject to random shocks (see Table 2, Panel D). The shock takes values of -50, -40, -30, -20, -10, 0, 10, 20, 30, 40, or 50 cents with equal probability. The expected revenues value for every investment-skill combination in the Risky Project is equal to the revenues value for the corresponding investment-skill combination in the Basic Project (Table 2, Panel A).

2.2.2. Real-effort treatment

In the Real-effort treatment, subjects exert real mental effort in the Strong Incentives and Loss Aversion Control Projects (Table 3 Panels A-B). We exclude the Basic project from the analysis because we can no longer control for subjective effort cost as we do in the Investment treatment via the monetary cost of investment. Different subjects are likely to derive different disutility from the same real-effort levels and subjects with lower disutility are likely to choose higher effort levels. In other words, we would not be able to distinguish subjects with low real-effort disutility from those who overestimate their skill level since intrinsic subjective real-effort disutility levels are unobservable.

[Insert Table 3 about here]

In the Real-effort treatment, subjects choose how much effort they want to exert by selecting a difficulty level of a decoding task, see Appendix B. Subjects need to decode a list of 30 long numbers and partition them into 10 different groups. Subjects choose difficulty levels corresponding to the number of groups from which to decode, while the length of the list stays the same. The easiest effort level of 20% corresponds to a list of 30 long codes from 2 groups; whereas in the effort level of 100% subjects need to decode a list of 30 long codes from 10 groups. Irrespective of difficulty level, all subjects have the same amount of time (150 s).[12]

The decoding task is boring, demands concentration, and does not require any specific prior knowledge or skill. This task nature guarantees that subjects do not choose higher effort levels because they enjoy doing the task or because they assign any intrinsic value to the accomplished work. Finally, the task does not require any specific skill, insuring that subjects have equal capabilities to complete it and that the choice of effort level is not driven by their talent or ability.

2.3 Final payment

The payment procedure is the same in both the Investment and Real-effort treatments. Before subjects receive any feedback about their performance, we collect their risk-preferences, social characteristics, as well as their beliefs about their own skill level and those of their peers. Then, subjects can see their realized earnings in each project and one project is randomly drawn to determine their final earnings. Finally, subjects write down their final earnings and their bank account number on a receipt, privately hand in their receipts to an experimenter, and leave the lab.

3. Results

To assess the generalizability of the effects of overconfidence on effort provision, the experiment was conducted with three different media and repeated with two different subject samples. The first subject sample consisted of 201 graduate and

[12] The time constraint is rigid in the sense that subjects cannot gain more time by performing the task faster and they are penalized for exceeding the time limit. To insure deliberate choices, subjects are familiarized with different difficulty levels before making their choices. Moreover, subjects cannot proceed until they perform the task 100% correctly.

undergraduate students (111 in the Investment and 90 in the Real-effort treatment) with majors predominantly in Business or Economics. They took part in a Z-tree-based experiment (Fischbacher 2007) at the CentERLab of Tilburg University, the Netherlands. The second subject sample consisted of 147 financial professionals (only the Investment treatment). Of these, 33 financial professionals participated in a paper version of the experiment at the Tias School for Business and Society, Tilburg University; and 114 financial professionals performed an on-line Qualtrics version (Qualtrics Labs Inc., Provo, UT) of the experiment.[13] Whereas students were provided with real monetary incentives (average final earnings were 12.84 Euro), the professionals in both cases made hypothetical choices. Henceforth, we label BSc/MSc students and financial professionals as 'students' and 'professionals', respectively. Depending on the treatment and medium, we also refer to Investment treatment student sample, Real-effort treatment student sample, paper-based professional sample, and web-based professional sample.

3.1 Subject characteristics

Our subject samples are characterized by the following features (see Table 4). First, the student sample is more heterogeneous in terms of gender and nationality than the professional sample. While there are 43.3% women among the students, there are only 11.6% women in the professional sample. There is also more variation in the nationalities among students (European and Asian subjects),[14] whereas the professional pool is dominated by Europeans, mostly Dutch. Then, our samples are relatively homogeneous in terms of major as both students (with current degrees in Economics and Business) and professionals have (had) financial economics in their university training. Moreover, a finance affinity is present in virtually all professionals' CVs: banking, financial consulting, and financial management are their occupations in almost equal parts. Finally, as would be expected, work experience varies across the subject samples. The students have little

[13] Financial professionals in our sample are financial managers, bankers, financial consultants, etc., who followed an executive education at Tias School of Business and Society (and are alumni of the Executive Master in Finance or Executive Master in Business Valuation). For the on-line version, we invited Tias alumni via private phone calls (and email). To insure single-time individual participation, they received a personal link to login into the Qualtrics software, valid for 6 weeks.

[14] All the experiments were conducted in English and all participants had had finance courses in English at university level.

or no experience in the financial industry,[15] whereas the professionals report extensive working experience: 104 out of 147 professionals (71%) have gained work experience of 12 years or more. Thus, our combined subject sample comprises participants with different personal characteristics and professional experience, who have a strong affinity to finance and economics through education and/or their professional activities.

[Insert Table 4 about here]

3.2 Skill and (over)confidence

To quantify actual skill, we use performance in the financial knowledge questionnaire (Table 5). On average, students give 13.75 correct answers, which is 1.73 and 3.36 fewer correct answers than professionals give in the paper- and web-based samples respectively (see column 1). Higher professionals' performance reasonably results in higher average confidence in their financial knowledge (see column 2). In the web-based professional sample, the subjects believe that on average 89.03% of their answers are correct, whereas the students estimate that only 85.37% of their answers are correct. In spite of a significant difference in the number of correct answers, the professionals in the paper- and web-based sample display similar levels of confidence.

[Insert Table 5 about here]

The difference in performance between the student and professional samples is likely due to the professionals' superior knowledge and practical experience in finance. Although they have little bearing on the primary focus of the paper (relation between confidence and effort choice), other points that may be worthy of brief consideration are the following. The difference between the paper- and web-based professional samples could result from relaxed time constraints and from a difference in education (as the latter had completed the executive finance programs whereas the former were only half-way). The subjects participating in the lab and paper-based experiments were given only a limited amount of time to answer 20 financial knowledge questions and to indicate their confidence levels. On the contrary, the subjects of the web-based version could spend as much time as they

[15] Though our final questionnaire did not have a direct question about students' working experience, we believe that this assumption is plausible as 90% of the students in our sample are 25 years old or younger.

wanted.[16] The professionals took longer to fill in the questionnaire than the students in the lab experiment (see column 3). However, the time spent to fill in the questionnaire did not increase subjects' performance. The correlation between response time and number of correct answers is not different from zero in both samples: for the students the correlation coefficient is 0.04 ($p = 0.63$) and for the professionals (web-based) it is -0.04 ($p = 0.67$).

To investigate whether subjective confidence levels accurately reflect their performance, we follow the psychology literature and calculate a calibration-based overconfidence measure, CBO. CBO is the difference between a subject's average confidence in her answers (Confidence) and the actual number of correct answers she gave, divided by 20 (the total number of questions). Positive values of CBO indicate that the subjects' confidence in their financial knowledge is higher than their actual performance and that they believed that they gave more correct answers than they actually did, i.e. they are overconfident. Negative CBO values imply that the subjects underestimate their financial knowledge.[17]

As expected, on average subjects are significantly overconfident, see column 4 of Table 5. The students overestimate their financial knowledge by 16.64%, the professionals by 13.67% and by 3.46% in the paper- and web-based experiment versions, respectively. In the lab environment (computerized or paper-based), both the students and professionals demonstrate similarly high levels of overconfidence (the diff. = 2.97, $t = 1.15$, $p > 0.10$). Although in the web-based version professionals appear to be better calibrated due to better performance, their average CBO of 3.46% is still significantly above zero ($t = 3.91$, $p < 0.001$). Here again, the time spent to answer the questions is not significantly correlated with CBO.

We also analyze whether subjects consider their financial knowledge to above the average financial knowledge. In the final questionnaire, subjects report their beliefs about the number of correct answers they and their peers gave in the financial knowledge questionnaire. We set a dummy variable BtA (better-than-

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[16] For the computerized (lab- and web-based) versions, individual response time is recorded. In the paper-based version, time was constant across subjects as they all received and handed in their questionnaires simultaneously, which obviously does not exclude some unobservable variation in response time.

[17] We also repeat all our analysis using an alternative measure of overconfidence, which is the difference between the number of correct answers the subject believes to give and the actual number of correct answers she gave. The results essentially are the same. We use CBO in the paper because it is the measure most-often used in the literature.

average) equal 1 for those subjects who believe to give more correct answers than their peers, and 0 otherwise; see Table 5, column 5. Despite the fact that on average subjects are well-calibrated (half of them believe to have above-average financial knowledge), only 63 percent estimate their performance correctly relative to the others.

3.3 (Over)confidence, investment, and effort

3.3.1 Confidence and effort/investment choice

To test prediction 1, we partitioned the subjects of each sample into four confidence-based quartiles with subjective confidence increasing by quartile. As the subjects' effort/investment choices do not significantly vary from one project to another, we calculate for every subject the Average Choice variable as his/her average effort/investment choice across the projects. For the Investment treatment student sample, we take the average investment level chosen by the subjects in the four projects (Basic, Strong Incentives, Loss Aversion Control, and Risky); for the Real-effort treatment student sample and both professional samples we use the average effort/investment level choice in the two projects (Strong Incentives and Loss Aversion Control). We compare the difference in the subjects' Average Choice across four Confidence-quartiles (see Figure 2).

[Insert Figure 2 about here]

Figure 2 provides strong support for prediction 1 and shows that in all samples, the chosen effort/investment level increases with Confidence. For instance, in the Investment treatment student sample, the subjects in the bottom quartile have the lowest Confidence and choose the lowest investment level of 2.68, whereas in the 2nd quartile, they choose an investment level of 3.20 (diff. = 0.52, $t = 2.11$, $p < 0.05$). In the 3rd and top quartiles, the students choose investment levels of 3.63 and 4.11 (diff. = 0.48, $t = 2.00$, $p = 0.05$). According to Figures 2.b, 2.c, and 2.d, the same pattern holds for the Real-effort student and both professional samples: chosen effort/investment grows with Confidence.[18]

[18] In the paper-based professional sample, the relationship is non-monotonic, most likely due to a small number of observations.

3.3.2 Overconfidence and effort/investment choice

To test prediction 2, we divide the subjects in each sample into four CBO-based quartiles with subjective overconfidence increasing by quartile. We refer to the difference between Average Choice and Actual Skill[19] as Excess Effort/Investment and compare it across the four CBO-quartiles for the student and professional samples (see Figure 3).

[Insert Figure 3 about here]

In the Investment treatment, the students' excess investment significantly varies across CBO quartiles (see Figure 3.a). Despite the fact that the students in the bottom CBO quartile appear to be unbiased (CBO equals to -0.15%, $t = 0.17$, $p > 0.10$), they systematically underinvest: Excess Investment is significantly negative ($t = 3.60$, $p < 0.001$). The subjects in the 2nd CBO quartile, with a moderately positive but significant CBO of 9.56% ($t = 17.80$, $p < 0.001$), select accurate investment levels: Excess Investment is zero. The highly overconfident subjects in the 3rd and top CBO quartiles choose excessively high investment levels: Excess Investment equals 1.00 and 1.78 respectively ($t = 4.20$ and $t = 9.12$ respectively, both p-values are less than 0.001). Thus, subjective under- and overconfidence result in under- and overinvestment, whereas moderate overconfidence leads to accurate decisions.

In the Real-effort treatment, we find the same pattern as in the Investment treatment (see Figure 3.b). In real life, the positive effect of overconfidence on effort is likely to be stronger for actually exerted effort than for monetary investments because individuals are likely to derive a certain utility from performing a task (Brüggen and Strobel 2007). For example, people dedicate time and real effort to voluntary work, but at the same time may be reluctant to provide an equivalent amount of money for the same purposes (van Dijk, Sonnemans, and van Winden 2001). Moreover, unlike in our design, in the real world skill generally can be substituted with effort at least to some extent and real job assignments tend to be more fun than our artificial task.[20]

Figures 3.c and 3.d present Excess Investment across CBO quartiles for the paper- and web-based professional samples. In line with our previous findings, the

[19] Actual Skill is defined in accordance with Table 1 and equals 1 if a subject gives 11 or less correct answers in the financial knowledge questionnaire, 2 if she gives 12 or 13 correct answers, 3 if 14 or 15, 4 if 16 or 17, and 5 if the subject answers 18, 19, or 20 questions correctly.

[20] Although we did not directly ask the subjects about their perception of the task, several of them said after the experiment that the task was boring and a "complete waste of time."

subjects in the bottom CBO quartile substantially underinvest: Excess Investment is -0.89 and -0.81 respectively (t = 2.29; t = 4.61, both p-values are less than 0.10). In the 2nd and 3rd CBO quartiles, the subjects are on average slightly overconfident and are well-calibrated in their choice of investment levels: the Excess Investment is not statistically different from zero. In the top CBO quartile, professionals are significantly overconfident and choose inappropriately high investment levels in both paper- and web-based samples.

Thus, our results demonstrate that subjective confidence leads to higher effort/investment levels in both the incentivized investment and real-effort domains (prediction 1). Moreover, despite the fact that real monetary rewards are at stake, both underconfidence and extreme overconfidence lead to suboptimal effort/investment choices and substantial losses (prediction 2). Taken together, moderately overconfident subjects (with a CBO of about 5-15% for the student sample and about 3-10% for the professional sample) tend to choose accurate investment levels, whereas those with higher/lower overconfidence choose inappropriately high/low investment levels. Out data suggest that professional experience and better financial knowledge may not affect the positive relation between confidence and chosen investment level.

One may argue that the above positive relation between confidence and chosen investment is mechanical and mostly driven by subjects' skill. For example, more skilled subjects can be rightfully more confident and therefore choose higher effort/investment levels. Moreover, according to our CBO measure, high-skilled subjects have less scope to be overconfident: given a fixed confidence level, a subject's CBO decreases with the number of correct answers given by the subject. To address this issue, we conduct a multivariate analysis, where we control for the subjects' actual skill and personal characteristics.

3.4 Regression analysis

Our main dependent variable is Average Choice; but we also repeat the analysis using subjects' effort/investment choice in each individual project. Our explanatory variables include Confidence, Actual Skill, and subjects' personal characteristics: gender, age, education, nationality, work experience, and occupation (the last two only apply to the professionals).[21] The results are reported in Table 6.

[Insert Table 6 about here]

We find that the coefficient of Confidence is positive and significant in all subject samples and in all specifications, including those for individual projects.[22] Thus, we confirm the results found in the previous section: the higher the subjects' confidence in their financial knowledge, the higher their chosen investment levels. In particular, Confidence has a positive effect on subjects' effort/investment choice in both the Investment and Real-effort treatments for the student sample (Table 6, Panels A and B). This finding corroborates that effort type (monetary investment vs. real effort) does not affect the positive relation between confidence and exerted effort/investment. Moreover, we observe no significant difference in the above relation for the paper-based and web-based professional samples (Table 6, Panels C and D). In other words, it does not matter whether the professionals performed the task in class with paper and pencil or at home in front of their computers.

Note that the coefficient of Actual Skill is consistently positive and significant only for the student samples (Table 6, Panels A and B) and is significantly smaller than 1. If subjects were able to predict their performance in the financial knowledge questionnaire perfectly, then a value of 1 would be expected for the Actual Skill variable and a value of 0 for the Confidence variable. Taken together, these results suggest that subjects' effort and investment choice strongly correlates with their confidence but not with their actual skill level.

To further test prediction 2 and to investigate how overconfidence and actual skill affect subjects' propensity to select an appropriate effort/investment level, we regress Excess Effort/Investment on the subjects' overconfidence levels, Actual Skill, and personal characteristics. The results are presented in Table 7.

[Insert Table 7 about here]

According to model (1), calibration-based overconfidence has a positive effect on excess effort/investment choice: the coefficients of CBO are positive and

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[21] We also measure subjects' risk aversion via the Holt and Laury (2002, 2005) task and cognitive reflection score (CRS) via Frederick's (2005) questions. Both risk aversion and CRS are insignificant in all regressions, including those run separately for every project and every sample. Our main results do not change, when we restrict the sample to high-CRS subjects only.

[22] To check for multicollinearity, we calculate variance inflation factors (VIF). For Confidence and Skill variables VIFs are never above 1.54 in all specifications.

significant for all subject samples. As there may be a multicollinearity issue between CBO and Actual Skill (their VIFs in model (1) are above 2.5), we make CBO and Actual Skill orthogonal by regressing CBO on Actual Skill and taking the residual (for models (2), (3), and (5)). This transformation does not affect the coefficient of CBO, but increases the coefficient of Actual Skill in absolute value (see model (2)). The coefficient remains negative and significant implying that subjects with higher skill are less likely to overinvest.[23]

To test the implication of prediction 2 that under- and overconfidence affect effort and investment choice similarly, we add to the regression a dummy variable, *I*(CBO>0) that equals 1 for positive CBO and 0 otherwise (see model (3)). From the above results (section 3.3.2) we expect a negative coefficient of *I*(CBO>0), meaning that only strong overconfidence positively affects effort/investment choice, while moderate overconfidence does not result in overinvestment. We find that the coefficient is significant and negative only for Investment treatment student sample (see Panel A, model (3)). Importantly however, for the rest of the subjects, the positive CBO dummy estimate is not significant (see Panels B-D, model (3)). Thus, we obtain no consistent evidence that under- and overconfidence differently affect decision-making, which is exactly what prediction 2 implies.

To test whether overestimating one's abilities relative to others affects one's effort/investment decisions, we regress Excess Effort/Investment on a dummy variable BtA (better-than-average; see model (4)). The coefficient of BtA is positive and significant for all subject samples. In model (5) we put both overconfidence measures, CBO and BtA, into the regression. The estimates for the CBO coefficient are relatively unaffected in comparison with model (2), but the coefficient of BtA stays significant only in the student samples (see Panels A and B). Thus, not only subjects' ability overestimation relative to their actual ability but also relative to the ability of others can positively affect subjects' propensity to overinvest and exert excess effort. However, overestimation appears to have a more robust effect than better-than-average.

[23] To check whether our results for the Actual Skill variable are not driven by the high-skilled subject sub-sample, who cannot overinvest by the constraints of the experimental design, we rerun the above regressions for subjects with skill levels from 1 to 4 and for subjects with skill levels from 1 to 3 for both the student and professional samples. The results essentially stay the same.

4. Discussion

Taken together, our data support predictions 1 and 2: the effort/investment levels chosen by the subjects are positively affected by their confidence levels. Subjects with high confidence in their financial knowledge tend to overinvest: they choose higher effort/investment levels in comparison with their less confident peers. Effort/investment levels are excessively high in case of strong overconfidence and inappropriately low in case of underconfidence. Moderately overconfident subjects (as measured by overestimation or CBO) which represent about 5-15% for the student sample and about 3-10% for the professional sample are more likely choose accurate effort/investment levels. These relations are independent of stake size. Previous literature also shows that overconfidence with very high stakes as in personal investment decisions or corporate decision-making, still leads to suboptimal choices. Overestimation of one's abilities leads to excess entry into competitive markets and substantial monetary losses (Camerer and Lovallo 1999). Moreover, overconfident individuals are more likely to self-select into convex (vs. linear) incentive schemes, generating personal losses even in the presence of clear feedback (Larkin and Leider 2012). Overconfident individual investors overestimate their ability to select good stocks and to time their trades. As a result, they engage in excessive trading and bear increased trading costs, which considerably reduce their net returns (Barber and Odean 2001; Fenton-O'Creevy et al. 2003; Merkle 2013).

In the corporate world, it is usually not managers themselves but rather their shareholders, who pay the costs of managerial hubris. Malmendier and Tate (2005a, 2005b) assume that overconfident managers overestimate their ability to create firm value and large returns to their investment projects. They show that overconfident CEOs make sub-optimal investments: in presence of excess cash, those CEOs overinvest in new projects, and underinvest (and thus forego investments yielding positive net present values) if they need to attract external funding and are hence forced to undergo the scrutiny of bank creditors or financial markets. Such (symmetrically) suboptimal investment strategies result in a higher cash-flow sensitivity of investments. Moreover, Malmendier, Tate, and Yan (2011) find that overconfident CEOs use less external capital and, in particular, issue less equity than their peers. The fact that overconfident CEOs prefer less control from the providers of outside funding which leads them to hoard cash is also reflected in their payout policy: they retain more cash and pay less dividends (Deshmukh et al. 2013). Moreover, overconfident CEOs make poor takeover decisions by paying higher takeover premiums than less overconfident CEOs (Malmendier and Tate 2008; Liu and Taffler 2008; Aktas et al. 2012). The pressure to deliver instigates overconfident CEOs to manage (or manipulate) earnings more often in comparison with their peers (Schrand and Zechman 2012; Hribar and Yang 2011).

Although all these previous findings suggest that (strong) overconfidence ends in poor decision making, it is important to note that these papers are using only proxies of overconfidence, e.g. press portraits, the managers' personal exposure to firm-specific risk captured by individual holdings of their firms' stock options, and the timing of option exercises. Despite their broad acceptance, the justification and consistence of those measures was so far rather low. For example, in the study by Malmendier and Tate (2008) the correlation between overconfidence proxies by press portraits and by managerial stock-option holdings is never above 0.10. Our study rationalizes the convention for using managers' investment decisions as proxy for their overestimation of their abilities as we confirm a positive relation between confidence and investment decisions. However, the relation between true managerial overconfidence and its perception by the press remains to be confirmed.

The theoretical literature predicts that in some cases, agents' overconfidence may result in Pareto-improvements or alleviate the negative effects of agents' risk aversion. Gervais and Goldstein (2007) study a model of a firm where the marginal productivity of agents' efforts is amplified by other agents' efforts. They show that in such a firm all agents can be better off in the presence of an overconfident agent, who overestimates his marginal productivity and applies excessive effort. Gervais et al. (2011) theoretically predict that moderately overconfident CEOs are preferred by boards of directors because it is cheaper for firms to motivate them to pursue valuable risky projects and also because they are committed to exert more effort to learn about the projects. Campbell et al. (2011) theoretically show that overconfidence reduces the underinvestment resulting from CEOs' risk aversion and, subsequently, moderately overconfident and risk averse CEOs invest at a level closer to the one preferred by risk-neutral shareholders. It is precisely the moderately overconfident subjects in our experiment who choose accurate effort and investment levels, whereas their well-calibrated peers underprovide effort/investment. In practice, managerial effort is not observable or measurable for researchers but available to boards of directors or employers. If indeed, as predicted by the theory and shown in our experiment, moderately overconfident managers do not only provide appropriate investment levels but also exert higher effort, then firms' preferences for such managers may be well justified. The same argument holds for overconfident workers and their employers.

Hirshleifer, Low, and Teoh (2012) suggest that the interplay between a CEO's risk-aversion and overconfidence plays a crucial role in her pursuit of innovative projects. They show that overconfident CEOs (proxied by stock-option holdings) invest more in R&D, achieve greater success in innovation, and are better in exploiting growth opportunities in innovative industries. Our results are in line with those of Hirshleifer et al. (2012) in the sense that CEOs overconfidence which triggers higher effort and investment, can be beneficial in the context of innovative projects (see also Galasso and Simcoe 2011). However, in a context where there is a danger of overinvestment such as empire-building, we expect strong overconfidence to be detrimental in terms of shareholder value. Moreover, given the higher risk and uncertainty in growth industries, higher levels of CEOs' overconfidence may be necessary to overcome their risk-aversion. Thus, as it would be optimal to attract more overconfident managers in riskier industries, one would expect a positive correlation between industry-specific risk levels and CEO overconfidence.[24]

While the effects of overconfidence on economic behavior have been studied (see Müller (2007) for a detailed review), relatively few papers examine the effects of underconfidence on individual decision-making. Individuals who underestimate their abilities may withdraw from certain activities or decrease their effort when it may be still beneficial for them to persist. In corporate decision-making, underconfidence is also likely to play an important role. Hence, we believe that further reseach should pay more attention to both under- and overconfidence and their effects on decision-making, rather than consider overconfidence alone.

Limitations

A caveat in relation to the web-based version of our experiment is that we cannot guarantee that professionals do not use external help while answering financial

[24] However, Graham, Campbell, and Puri (2013) find that growth companies are more likely to employ more risk-tolerant and not more optimistic CEOs.

knowledge questions. Yet, we believe that potential cheating was very limited for several reasons. First, the subjects were explicitly asked not to use any external sources to check their answers: once in the invitation (two thirds of the participants were personally rang – all the ones who could be reached by phone within two calling attempts - and asked to give their word not to use any help and one third was reached by e-mail and received the same request) and also in the experimental instructions. The ones who were reached by phone gave their word of honor that they would not look up answers on the web. Second, checking the answers would have made the professionals in the web-based sample more confident in their answers: they would have known for sure that their answers were correct. However, their confidence was not significantly different from that of the professionals in the paper-based sample. Third, professionals could not acquire any monetary or prestige benefits from cheating, which also discourages lying behavior (Gneezy 2005); indeed, they were guaranteed that their answers would be treated confidentially.

The next caveat to our design concerns the different incentives used for students and professionals. We deliberately asked professionals to make only hypothetical choices mostly for reasons of cheating-prevention (see above) and anonymity. In the web-based sample, asking for subjects' names and bank account numbers to transfer their earnings would strip the professionals of their anonymity. Moreover, while for students opportunity costs were alike and equal to an average hourly wage for unqualified labor force, opportunity costs for professionals are likely to be much more heterogeneous, depending on qualification, current position, age, etc. So even paying "an average professional hourly wage" would not make professionals' incentives equal within the sample. In this, we follow Biais and Weber (2009) who incentivized students but not professionals.

Finally, our design does not allow for learning as no feedback is provided before subjects make their effort/investment decisions. Providing feedback could weaken the relationship between confidence and effort/investment, which is the main objective of study. Still, providing feedback is unlikely to totally eliminate the relation between confidence and effort/investment, especially in real life where feedback is often noisy and negative feedback is often largely ignored (Hilary and Menzly 2009).

5. Conclusion

Self-confidence is considered as a valuable individual trait because it enhances motivation and stimulates a person to reach profitable long-term goals, even when facing short-term negative outcomes. This study considers how individuals' confidence in their own abilities affects their decision to provide more or less effort both in real and monetary terms. Despite the strong monetary incentives to accurately estimate their skill levels, many subjects in our experiment appear to misjudge their abilities systematically: higher confidence results in higher effort/investment levels. Whereas moderate overconfidence is still advantageous and leads to accurate effort/investment levels, both extreme overconfidence and underconfidence results in considerable costs and suboptimal (corporate) decision making. Subjects who are substantially overconfident with respect to their own skill (in absolute terms or relative to their peers) choose inappropriately high effort/investment levels, whereas underconfident subjects apply insufficient effort/investment. Our results are robust for professionals and lay men (students in economics, finance, and business) with knowledge in the same domain as the decision task, across lab-, paper-, and web-based experimental designs, and across two different types of effort, monetary investment and the exertion of real effort.

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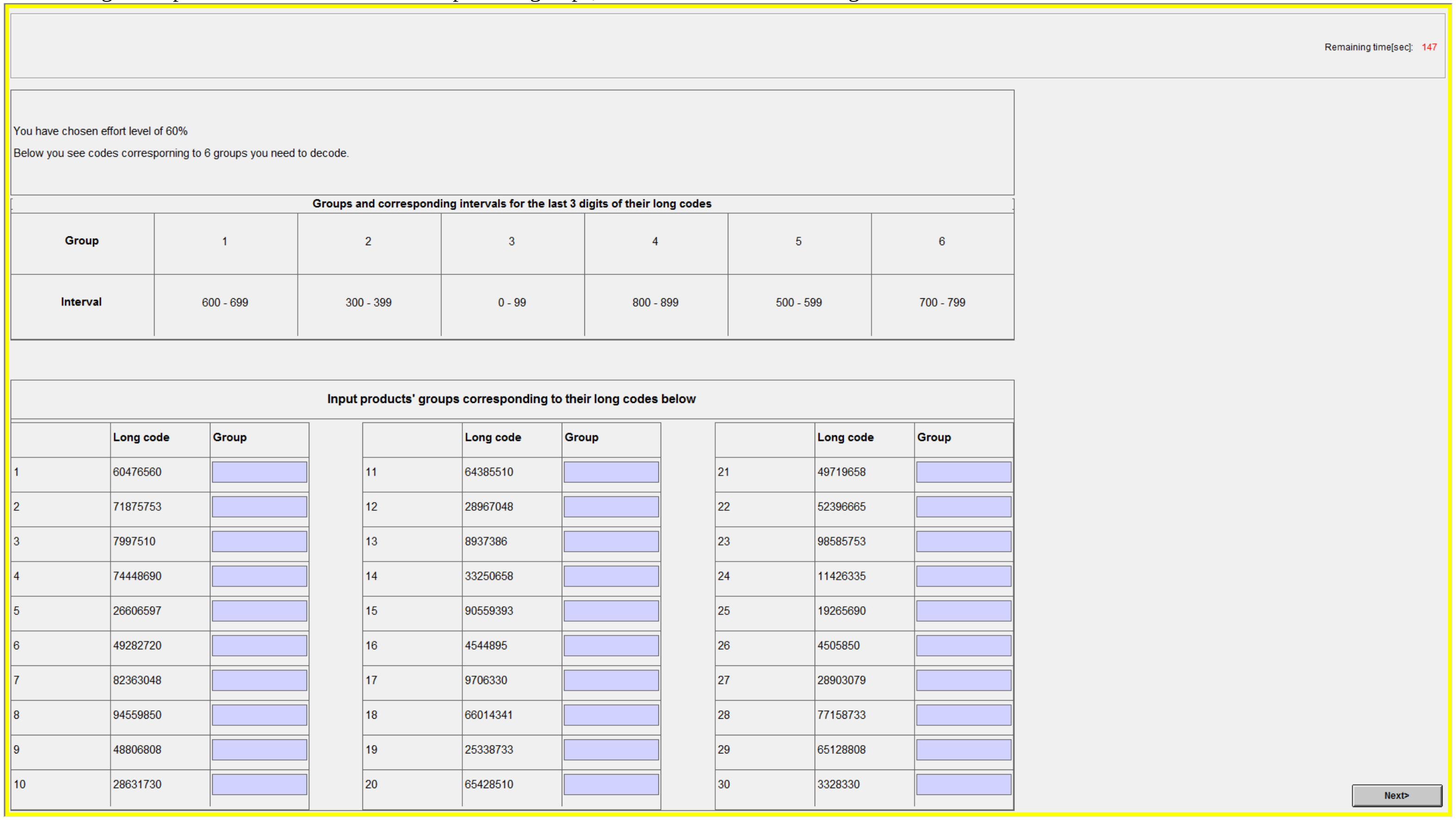
Appendix A Financial Knowledge Questionnaire

Appendix A presents financial knowledge questions with two alternative answers; the correct one is in bold.

1. Inflation may create problems in many ways. Which group would have the greatest problem during periods of high inflation that last several years? **(i) Older people living on fixed retirement income;** (ii) Young working couples with children and a mortgage.
2. If interest rates rise, what will typically happen to bond prices? **(i) Fall;** (ii) Rise.
3. Buying a single company's stock usually provides (i) a safer return than a stock mutual fund; **(ii) a riskier return than a stock mutual fund.**
4. Justin just found a job with a take-home pay of 2,000 Euro per month. He must pay 800 Euro for rent and 200 Euro for groceries each month. He also spends 200 Euro per month on transportation. If he budgets 100 Euro each month for clothing, 150 Euro for restaurants and 250 Euro for everything else, how long will it take him to accumulate savings of 900 Euro. (Assume no interest rate payment on savings). **(i) 3 months;** (ii) 5 months.
5. A young person with $100,000 to invest should hold riskier financial investment than an older person with $100,000 to invest. **(i) True;** (ii) False.
6. In investor wants to buy a house but does not have sufficient funds. He invests in a risky project and his investment (including the returns) doubles in size every quarter. If it takes 48 quarters to reach the necessary funds to purchase the house, how many quarters would it take to have sufficient funds to purchase half of the house? (i) 24 quarters; **(ii) 47 quarters.**
7. Scott and Eric are young men. Each has a good credit history. They work at the same company and make approximately the same salary. Scott has borrowed 6,000 Euro to take a foreign vacation. Eric has borrowed 6,000 Euro to buy a car. Who is likely to pay the lowest finance charge? **(i) Eric will pay less because the car is collateral for the loan;** (ii) They will both pay the same because consumer credits have the same interest rate.
8. Elena started her pension program at age 20 and put in €2,000 each year for 15 years. Rebecca started her pension program at age 35 and put in €2,000 each year for 30 years. If they both get 6% per year on their investments, who will have more money at age 65? **(i) Elena;** (ii) Rebecca.
9. Employees should have the majority of their retirement funds in their current employers stock. (i) True; **(ii) False.**
10. If it takes 5 machines 5 minutes to make 5 widgets, how long would it take 100 machines to make 100 widgets? **(i) 5 minutes;** (ii) 100 minutes.
11. It is possible for investors to be diversified even if they invest all their money in one mutual fund. **(i) True;** (ii) False.
12. You would rather have $5,000 or a Euro cent doubled every day for a month? (i) True; **(ii) False.**
13. Yolanda has three credit cards and she owes €500 on each of them. The interest rates are 7% for card A, 9% for card B and 8% for card C. If Yolanda has €1,000 to pay some of her debt, which cards should she pay if she wants to minimize future interest payments? **(i) €500 to card B and €500 to card C;** (ii) €333 to card A and €334 to card B and €333 to card C.
14. How do income taxes affect the income that people have to spend? (i) They decrease spendable income in deflationary times and increase spendable income in inflationary times. **(ii) They decrease the amount of goods and services that can be purchased.**
15. A bat and a ball cost 1.10 Euro in total. The bat cost 1 Euro more than the ball. How much does the ball cost? (i) 0.10 Euro; **(ii) 0.05 Euro.**
16. At takeovers, the bidding firm usually pays a large premium to the target firm. Therefore, upon announcement, the target firm’s share price increases substantially as it anticipates the premium to be paid in the takeover. Hence, if you own shares of a target firm (before the announcement), you will very likely make a large profit if you sell them after the announcement. **(i) True;** (ii) False.
17. You invest 1000 in a project and the discount factor is 10%. The return is expected to be 1100 in year 1 and 1200 in year 2 (when the project ends). The net present value is approximately: **(i) 1000;** (ii) 1300.
18. If you have to sell one of your stocks, you should sell one which has gone up in price rather than one which has gone down. (i) True; **(ii) False.**
19. To do well in the stock market, you should buy and sell your stocks often. (i)True; **(ii) False.**
20. The cost of capital of the average listed firm consists is about **(i) 10%;** (ii) 20%.

Appendix B Real Effort task

Appendix B presents a shot screen of the decoding task in the Real-Effort treatment. The shot screen below demonstrates a task for effort level 3 (or 60%), which corresponds to decoding of 30 product codes into 6 different product groups, based on their last three digits.



Remaining time[sec]: 147

You have chosen effort level of 60%

Below you see codes corresporning to 6 groups you need to decode.

Groups and corresponding intervals for the last 3 digits of their long codes

Group	1	2	3	4	5	6
Interval	600 - 699	300 - 399	0 - 99	800 - 899	500 - 599	700 - 799

Input products' groups corresponding to their long codes below

	Long code	Group		Long code	Group		Long code	Group
1	60476560		11	64385510		21	49719658	
2	71875753		12	28967048		22	52396665	
3	7997510		13	8937386		23	98585753	
4	74448690		14	33250658		24	11426335	
5	26606597		15	90559393		25	19265690	
6	49282720		16	4544895		26	4505850	
7	82363048		17	9706330		27	28903079	
8	94559850		18	66014341		28	77158733	
9	48806808		19	25338733		29	65128808	
10	28631730		20	65428510		30	3328330	

Next>

Figure 1 Production and Effort Cost Functions

This figure depicts how effort cost and project value depend on managerial effort e. A manager's productivity is also positively related to her skill level s, $s_l < s < s_h$. An overconfident manager ($\tilde{s}_{oc} = s_h$) chooses higher than optimal effort level, $e^*(s_h) > e^*$ and bears unnecessary costs that decrease her final utility; whereas an underconfident manager $\tilde{s}_{uc} = s_l$ chooses sub-optimally low effort level $e^*(s_l) < e^*$ and suffers from underproduction.

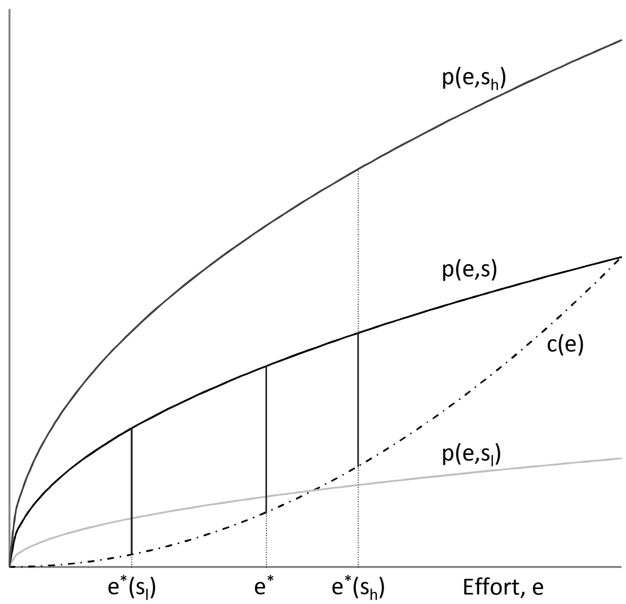


Figure 2 Investment and Effort Choices across Confidence Quartiles

Figure 2 presents the subjects' average investment and effort choice across Confidence quartiles, whereby the top quartile consists of the subjects with the highest level of confidence. **Confidence** is the subject's average confidence in her answers across 20 financial questions. **Average Choice** is the average investment/effort level choice across all available projects.

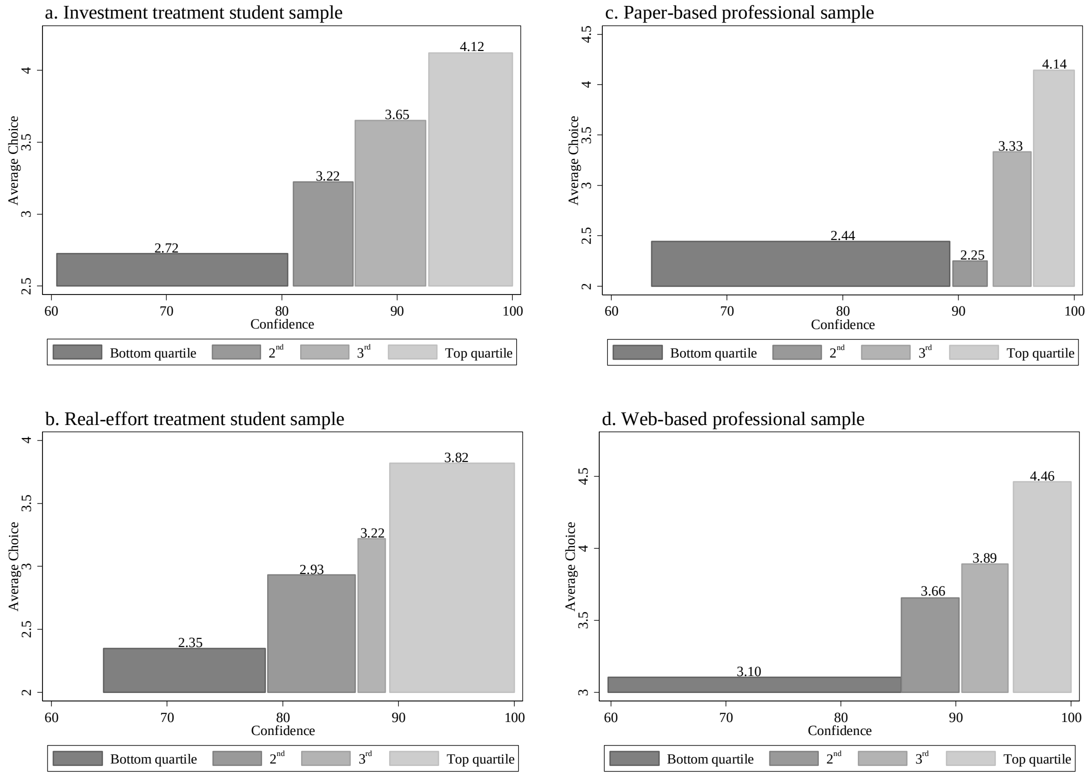


Figure 3 Excess Investment and Effort across CBO Quartiles

Figure 3 shows subjects' average **Excess Investment** and **Excess Effort** across CBO quartiles, whereby the top quartile consists of the subjects with the highest level of overconfidence. **Excess Investment/Effort** is defined as the difference between Average Choice and Actual Skill. **Average Choice** is the average investment/effort level choice across all available projects. **Actual Skill** level equals 1 if a subject gives 11 or less correct answers in the financial knowledge questionnaire, 2 if she gives 12 or 13 correct answers, 3 if 14 or 15, 4 if 16 or 17, and 5 if the subject answers 18, 19, or 20 questions correctly. **CBO** (Calibration-based overconfidence) is the difference between the average subject's confidence in her answers and the actual number of correct answers she gave, divided by 20 (the total number of questions). * stands for $p<0.10$, ** for $p<0.05$, and *** for $p<0.01$ of two-tailed t-test.

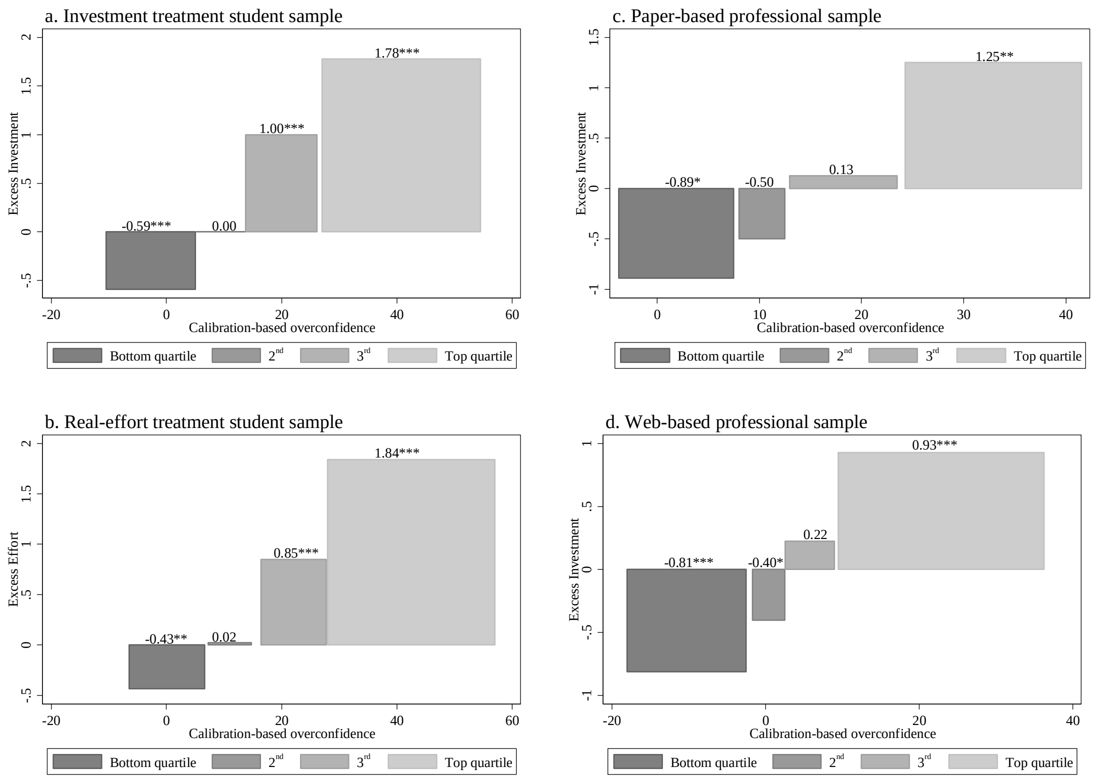


Table 1 Number of Correct Answers and Skill Level

Table 1 presents the relation between the number of correct answers given by a subject in Part 1 and the skill level assigned to her in Part 2. The number of correct answers required for a certain skill level is defined in such a way that the proportion of subjects in each skill group is approximately the same (following a pre-experimental pilot study). None of the subjects from the pilot study participated in the subsequent main experiment.

Number of correct answers	11 or less	12 or 13	14 or 15	16 or 17	18 or more
Skill level	1	2	3	4	5

Table 2 Projects within the Investment Treatment

Table 2 presents the revenues and investment cost (both in cents) depending on a subject's actual skill level and chosen investment level by project in the Investment treatment. The realized revenues are determined by the subject's choice of investment level and her actual skill level. The investment cost (last column) depends only on the chosen investment level and does not depend on the subject's skill level. In each project, the subject's final earnings are equal to revenues plus an endowment (of 500 cent) minus the investment cost.

Panel A Basic Project

	Revenues depending on investment level and skill					
Investment level	**Skill 1**	**Skill 2**	**Skill 3**	**Skill 4**	**Skill 5**	**Cost of investment**
1	400	490	530	550	565	60
2	440	600	690	750	765	130
3	475	650	850	950	980	220
4	505	700	900	1150	1220	340
5	530	750	950	1230	1500	500

Panel B Strong Incentives Project

	Revenues depending on investment level and skill					
Investment level	**Skill 1**	**Skill 2**	**Skill 3**	**Skill 4**	**Skill 5**	**Cost of investment**
1	400	0	0	0	0	60
2	0	600	0	0	0	130
3	0	0	850	0	0	220
4	0	0	0	1150	0	340
5	0	0	0	0	1500	500

Panel C Loss Aversion Control Project

	Revenues depending on investment level and skill					
Investment level	**Skill 1**	**Skill 2**	**Skill 3**	**Skill 4**	**Skill 5**	**Cost of investment**
1	850	0	0	0	0	220
2	0	850	0	0	0	220
3	0	0	850	0	0	220
4	0	0	0	850	0	220
5	0	0	0	0	850	220

Panel D Risky Project

	Revenues depending on investment level and skill					
Investment level	**Skill 1**	**Skill 2**	**Skill 3**	**Skill 4**	**Skill 5**	**Cost of investment**
1	350-450	440-540	480-580	500-600	515-615	60
2	390-490	550-650	640-740	700-800	715-815	130
3	425-525	600-700	800-900	900-1000	930-1130	220
4	455-555	650-750	850-950	1100-1220	1170-1270	340
5	480-580	700-800	900-1000	1180-1280	1450-1550	500

Table 3 Projects within the Real-effort Treatment

Table 3 presents the rewards (in cents) which depend on the subject's actual skill level and the chosen effort level by project within the Real-effort treatment. The realized revenues are determined by the subject's choice of effort level and her actual skill level.

Panel A Strong Incentives Project

	Reward depending on effort level and skill				
Effort level	**Skill 1**	**Skill 2**	**Skill 3**	**Skill 4**	**Skill 5**
20%	900	0	0	0	0
40%	0	1100	0	0	0
60%	0	0	1350	0	0
80%	0	0	0	1650	0
100%	0	0	0	0	2000

Panel B Loss Aversion Control Project

	Reward depending on effort level and skill				
Effort level	**Skill 1**	**Skill 2**	**Skill 3**	**Skill 4**	**Skill 5**
20%	1350	0	0	0	0
40%	0	1350	0	0	0
60%	0	0	1350	0	0
80%	0	0	0	1350	0
100%	0	0	0	0	1350

Table 4 Subjects' Characteristics

Table 4 presents the subject characteristics across different subject samples: Business and Economics students, and financial professionals. We collect the following information about the subjects during the final questionnaire: **Age**, gender (**Female** equals 1 for female subjects and 0 otherwise), **Nationality**, education (**Graduate** equals to 1 for students studying for a Master degree and 0 otherwise; **University degree** equals to 1 for professionals who have received a university degree (prior to their executive degree – at university) and 0 otherwise (a vocational degree); current **Degree** for students, where Finance, Econometrics/Operations Research, Accounting, Marketing, and Organization and Strategy majors are classified as 'Business', and **Occupation** and **Working Experience** for professionals.

Panel A Students

	Investment treatment		**Real-effort treatment**	
	Value	As %	Value	As %
Number of subjects	111	100	90	100
Average age (years)	22		22	
Female	45	40.5	42	46.7
Graduate	55	49.6	43	47.9
Nationality				
European / Dutch	60 / 47	54.1 / 42.3	62 / 46	68.9 / 51.1
Asian / Chinese	46 / 44	41.4 / 39.6	26 / 23	28.9 / 25.6
Other	5	4.5	2	2.2
Degree				
Business	34	30.6	36	40.0
Economics	51	46.0	35	38.9
Other	26	23.4	19	21.1

Panel B Professionals

	Paper-based		**Web-based**	
	Value	As %	Value	As %
Number of subjects	33	100.0	114	100.0
Female	7	21.2	10	8.8
Age				
Below 35 years old	10	30.3	23	20.2
Between 35 and 45 years old	12	36.4	58	50.9
Above 45 year old	11	33.3	33	28.9
Nationality				
European / Dutch	32 / 30	97.0/90.9 / 6.1	113 / 101	99.1 / 88.6
Asian	1	3.0	0	0.0
Other	0	0	1	0.9
University degree	26	78.8	110	96.4
Working experience				
Less than 8 years	6	18.2	15	13.2
8-11 years	7	21.2	15	13.2
12-16 years	7	21.2	41	36.0
More than 16 years	13	39.4	43	37.6
Occupation				
Banking	9	27.3	24	11.1
Consulting	6	18.2	30	26.3
Finance	6	18.2	35	30.7
Management	4	12.1	14	12.3
Self-Employed	6	18.2	7	6.1
Other	2	6.1	4	3.5

Table 5 Number of Correct Answers, Confidence, and Overconfidence

Panel A presents the summary statistics of the number of correct answers given by the subjects, their time spent answering the financial knowledge questions, the calibration-based (CBO), and better-than-average (BtA) overconfidence measures. Panel B presents the results of a t-test, non-parametric median test, and non-parametric Mann-Whitney test. **Confidence** is the average subject's confidence in her answers across 20 financial knowledge questions. **Time spent** is the number of seconds spent by subjects to answer 20 financial knowledge questions in the lab or web-based versions of the experiment. **CBO** is the difference between the average subject's confidence in her answers (Confidence) and the actual number of correct answers she gave divided by 20 (the total number of questions). **BtA** equals 1 for those subjects who believe that they gave more correct answers than their peers, and 0 otherwise. * stands for p<0.10, ** for p<0.05, and *** for p<0.01.

	(1) # of Correct Answers	(2) Confidence, %	(3) Time spent, sec.	(4) CBO, %	(5) BtA
Panel A Summary Statistics					
All subjects, 348 observations					
Mean	15.01	87.07	937.5	12.04	0.50
Median	15.00	88.25	781.0	9.40	0.00
Students, 201 obs.					
Mean	13.75	85.37	743.5	16.64	0.52
Median	14.00	86.25	738.0	14.00	1.00
Professionals, paper-based, 33 obs.					
Mean	15.48	91.09	-	13.67	0.27
Median	16.00	92.50	-	12.50	0.00
Professionals, web-based, 114 obs.					
Mean	17.11	89.03	1279.5	3.46	0.52
Median	17.00	90.25	1133.6	2.50	1.00
Panel B Tests					
Students vs. Professionals, web-based					
Difference in means	3.36	3.66	536.0	-13.18	0.00
t-statistic	11.06***	3.83***	7.61***	8.86***	0.08
Difference in medians	2.00	4.00	395.6	-11.50	0.00
Chi2-statistic	65.00***	12.22***	19.19***	46.56***	-
z-score Mann-Whitney test (H0: distributions are equal)	9.68***	4.05***	5.96***	8.14***	0.08
Professionals, paper-based vs. Professionals, web-based					
Difference in means	1.63	-2.06	-	-10.20	0.25
t-statistic	4.00***	1.39		5.29***	2.52**
Difference in medians	1.00	-2.25	-	-10.00	1.00
Chi2-statistic	10.04***	0.66		17.33***	6.17**
z-score Mann-Whitney test (H0: distributions are equal)	3.45***	1.67	-	4.63***	2.48**

Table 6 Impact of Confidence on Subjective Investment and Effort Choice

Table 6 presents the OLS models of subjective effort/investment choice. The dependent variables are **Average Choice** (average investment/effort level choice across all available projects) and investment/effort levels in each individual project. The main explanatory variables are Confidence and Actual Skill. **Confidence** is the subject's average confidence in her answers in the financial knowledge questionnaire. **Actual Skill** level equals 1 if a subject gives 11 or less correct answers in the financial knowledge questionnaire, 2 if she gives 12 or 13 correct answers, 3 if 14 or 15, 4 if 16 or 17, and 5 if the subject answers 18, 19, or 20 questions correctly. Each regression includes controls for subjects' gender, age, degree, nationality, and work experience and occupation (the latter two variables are for professionals only).
* stands for p<0.10, ** for p<0.05, and *** for p<0.01. Robust standard errors are in parentheses.

	Dependent variable				
		Investment/Effort level choice			
	Average Choice, all Projects	**Strong Incentives Project**	**Loss Aversion Control Project**	**Basic Project**	**Risky Project**
Panel A Students, Investment Treatment, 111 obs.					
Confidence	0.048***	0.066***	0.041***	0.043***	0.039***
	(0.011)	(0.010)	(0.015)	(0.014)	(0.014)
Actual Skill	0.164**	0.145*	0.169**	0.158*	0.184**
		(0.077)			
	(0.073)		(0.085)	(0.081)	(0.084)
Subjects' traits	Yes	Yes	Yes	Yes	Yes
Adj R^2	0.319	0.396	0.228	0.216	0.223
Panel B Students, Real-effort Treatment, 90 obs.					
Confidence	0.063***	0.068***	0.059***		
	(0.013)	(0.016)	(0.013)		
Actual Skill	0.195**	0.148	0.242**		
	(0.087)	(0.095)	(0.093)		
Subjects' traits	Yes	Yes	Yes		
Adj R^2	0.312	0.281	0.242		
Panel C Professionals, paper-based investment treatment, 33 obs.					
Confidence	0.099***	0.099***	0.099***		
	(0.020)	(0.020)	(0.020)		
Actual Skill	0.144	0.144	0.144		
	(0.142)	(0.142)	(0.142)		
Subjects' traits	Yes	Yes	Yes		
Adj R^2	0.363	0.363	0.363		
Panel D Professionals, web-based investment treatment, 114 obs.					
Confidence	0.059***	0.031*	0.086***		
	(0.0121)	(0.0159)	(0.017)		
Actual Skill	0.118	-0.021	0.257**		
	(0.078)	(0.123)	(0.104)		
Subjects' traits	Yes	Yes	Yes		
Adj R^2	0.270	0.114	0.270		

Table 7 Impact of Overconfidence on Excess Investment and Excess Effort

Table 7 presents the OLS models of Excess Investment and Excess Effort. The dependent variable, **Excess Investment/Effort,** is defined as the difference between Average Choice and Actual Skill. The main explanatory variables are CBO, BtA, and Actual Skill. **Average Choice** and **Actual Skill** are defined as in Table 6. **CBO** is the difference between the average subject's confidence in her answers and the actual number of correct answers she gave divided by 20 (the total number of questions). In models (2)-(5), CBO and Actual Skill are made orthogonal by regressing CBO on Actual Skill and taking the residual. **BtA** equals 1 for subjects who believe that they gave more correct answers than their peers, and 0 otherwise. Each regression includes controls for subjects' gender, age, degree, nationality, and work experience and occupation (the latter two variables are for professionals only). * stands for p<0.10, ** for p<0.05, and *** for p<0.01. Robust standard errors are in parentheses.

	(1)	(2)	(3)	(4)	(5)
Panel A Students, Investment Treatment, 111 obs.					
CBO	0.038***	0.038***	0.064***		0.033***
	(0.010)	(0.010)	(0.016)		(0.008)
I(CBO>0)			-0.549**		
			(0.270)		
BtA				0.897***	0.831***
				(0.198)	(0.186)
Actual Skill	-0.414***	-0.742***	-0.761***	-0.830***	-0.837***
	(0.109)	(0.070)	(0.069)	(0.072)	(0.072)
Subjects' traits	Yes	Yes	Yes	Yes	Yes
Adj R^2	0.573	0.573	0.585	0.605	0.647
Panel B Students, Real-effort Treatment, 90 obs.					
CBO	0.045***	0.045***	0.045***		0.031**
	(0.012)	(0.012)	(0.016)		(0.013)
I(CBO>0)			-0.000		
			(0.297)		
BtA				0.834***	0.647***
				(0.193)	(0.215)
Actual Skill	-0.301*	-0.687***	-0.687***	-0.818***	-0.752***
	(0.159)	(0.098)	(0.099)	(0.091)	(0.096)
Subjects' traits	Yes	Yes	Yes	Yes	Yes
Adj R^2	0.536	0.536	0.530	0.553	0.586
Panel C Professionals, paper-based investment treatment, 33 obs.					
CBO	0.078***	0.078***	0.086*		0.054*
	(0.019)	(0.019)	(0.045)		(0.029)
I(CBO>0)			-0.129		
			(0.822)		
BtA				1.529***	1.004
				(0.387)	(0.609)
Actual Skill	-0.066	-0.603***	-0.617***	-0.904***	-0.792***
	(0.182)	(0.144)	(0.149)	(0.171)	(0.194)
Subjects' traits	Yes	Yes	Yes	Yes	Yes
Adj R^2	0.388	0.388	0.359	0.373	0.431
Panel D Professionals, web-based investment treatment, 114 obs.					
CBO	0.051***	0.051***	0.038**		0.049***
	(0.011)	(0.011)	(0.018)		(0.011)
I(CBO>0)			0.249		
			(0.266)		
BtA				0.355*	0.259
				(0.181)	(0.169)
Actual Skill	-0.375***	-0.695***	-0.684***	-0.774***	-0.722***
	(0.117)	(0.079)	(0.084)	(0.077)	(0.079)
Subjects' traits	Yes	Yes	Yes	Yes	Yes
Adj R^2	0.479	0.479	0.480	0.404	0.486

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