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Do overconfident and over-optimistic entrepreneurs invest too much in their companies? Theory and evidence from Italian SMEs

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Abstract

Research summary
Entrepreneurs often invest a large share of their personal wealth in their firms, exposing themselves to idiosyncratic risk. We propose a theoretical model showing how overconfidence and over-optimism may help to explain this evidence. We focus on overprecision, but we also consider overestimation and overplacement. Numerical examples show a more substantial role for overconfidence than over-optimism in determining entrepreneurs' portfolio allocations. We test the effect of the two latent variables – overconfidence and over-optimism – on small business owners' portfolio allocations. We use a unique dataset including private information on Italian small and medium enterprises and a structural equation modeling approach. A positive relationship between overconfidence and entrepreneurs' investments in their own companies is confirmed.

Managerial summary
We propose a theoretical model showing how overconfidence and over-optimism explain the evidence that entrepreneurs invest a large share of their personal wealth in their firms, exposing themselves to specific risk. Overconfidence leads to underestimating risk, while over-optimism to overestimate expected returns. Using numerical examples, we show a more substantial role for overconfidence than over-optimism in determining entrepreneurs' portfolio allocations. Using a unique dataset including private information on Italian small and medium enterprises, we test our model and find a positive relationship between overconfidence and small business owners' investments in their own companies.

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Introduction

Entrepreneurs often hold a higher stake in their companies than a rational risk-return analysis would suggest. The larger the share of personal wealth invested in their companies, the greater (and more costly) the exposure to idiosyncratic risk. If entrepreneurs over-invest in their firms, they also face a higher cost of equity than diversified investors (Kerins *et al*., 2004; Pattitoni *et al*., 2013a) and a consequent decrease in firm value (Abudy *et al.*, 2016).

Despite several potential explanations, the debate is still open about why entrepreneurs invest so much in their firms. Thus, we propose a theoretical framework that shows how behavioral biases may, at least in part, explain this entrepreneurial decision.

We focus on overconfidence and over-optimism as two of the most prominent behavioral biases, distinguishing between their effects. Our stance is categorical and straightforward: while overconfidence leads entrepreneurs to underestimate risk, over-optimism causes them to overvalue the expected return of investing in their enterprises (de Meza and Southey, 1996; Simon *et al.*, 2000; Shefrin, 2005). We believe that these behavioral biases lead entrepreneurs to invest too heavily in their firms (Shefrin, 2011), so it is crucial to analyze the potential joint effects of behavioral biases in an entrepreneurship model. Models considering only one of the two biases or treating them separately may fail to grasp the whole picture, leading to inaccurate inferences (Chen et al., 2018).

To the best of our knowledge, ours is the first explicit measure of the potential bias brought about by overconfidence and over-optimism in entrepreneurial wealth allocation decisions. In doing so, we contribute an explanation of entrepreneurial overinvestment and under-diversification.

We use a portfolio model that considers both behavioral biases and clarifies how they affect entrepreneurs' risk-return analyses (Markowitz, 1952, 1959) and the crucial decision about what fraction of their total wealth to invest in their firm.

Our theoretical model helps explain the observed entrepreneurs' over-investment phenomenon. We then calculate how distinct levels of overconfidence and over-optimism affect entrepreneurs' portfolio choices using a numerical example of the results obtained in the theoretical model. Consistent with Ben-David *et al.* (2007), we have found a more substantial role for overconfidence than over-optimism in determining investment level in entrepreneurs' private firms. The numerical example also shows the overconfidence and over-optimism levels implicit in observable portfolio choices.

Finally, based on a unique dataset including data on small and medium enterprises (SMEs) in Italy and a structural equation modeling (SEM) approach, we test our theoretical and numerical predictions on the effect of latent behavioral biases on entrepreneurs' choices. While our model generally refers to entrepreneurs, our sample comprises small business owners (SBOs). Thus, we specifically refer to them in our empirical analysis.

The variables used to measure our latent constructs were deliberately chosen *ex ante*, and inserted in the survey to identify the two behavioral biases. They are based on established personal attitudes and characteristics previously associated with overconfidence and over-optimism in the behavioral finance literature.

To measure overconfidence, we use five variables related to SBOs' personal characteristics: *BTA*, to identify the so-called 'Better Than Average' effect[1]; *Male*, to grasp gender differences; *Height*, to consider stature; *Dedication* to work; *Perseverance*, a 'never give up' attitude.

We use four variables to measure over-optimism, one to account for dispositional optimism (Scheier and Carver, 1985) and the other three for unrealistic optimism. The variable designed to identify dispositional optimism is the so-called 'Rose-Colored Glasses' (RCG), based on positive or negative perception of life events (Dawson and Henley, 2012). To grasp unrealistic optimism, we use three variables. The first one, *Accidents*, measures SBOs' perception of the probability of having accidents, compared to the industry average. The second one, *Damages*, measure SBOs' subjective probability of causing damages, compared to the industry average. Both measures refer to the so-called 'comparative optimism' (Weinstein, 1980), which is a tendency to underestimate the chances of unfortunate life events compared to others. The third variable measuring unrealistic optimism identifies whether SBOs save funds to deal with emergencies, indirectly indicating their assessment of the chance of having accidents or causing damages (Weinstein, 1980; Dawson, 2017; Guiso and Schivardi, 2017). We provide a detailed description of these variables in Table 2, accompanied by references to the related behavioral finance and psychology literature. We also discuss these variables in the *Background Literature* and *Measurement Variables and Descriptive Statistics* sections.

This complete set of variables allows us to measure the two latent behavioral biases and find a positive and significant relationship between overconfidence and SBOs' investments in their companies. The role of over-optimism seems to be less relevant, in line with previous studies (e.g., Chen *et al.*, 2018) that find overconfidence particularly harmful.

[1] Sometimes referred as the 'Better Than Median' effect when, more properly, the median is used rather than the mean, as suggested by Moore and Schatz (2017). See the *Background Literature* and *Measurement Variables and Descriptive Statistics* sections for further details.

This result holds for our specific sample of small business owners of mature small and medium enterprises. On the other hand, our theoretical model allows for both overconfidence and over-optimism to influence entrepreneurs' choice of how much to invest in their private companies. Thus, we do not assume in general that overconfidence has a theoretical primacy over over-optimism.

The paper is organized as follows: the following section presents a literature survey; the third section proposes our theoretical model and a numerical example; the fourth section illustrates our empirical analysis, and the final section provides concluding remarks.

Background Literature

Literature on entrepreneurs' overinvestment and under-diversification has grown substantially. However, there is still debate among scholars as to why entrepreneurs invest so heavily in their own firms, overexposing the firm to idiosyncratic risk, without being compensated for by an adequate risk premium (Moskowitz and Vissing-Jørgensen, 2002; Fossen, 2011; Mueller, 2011). Explaining under-diversification is crucial given the consequences of the costly exposure to idiosyncratic risk.

Some studies show that entrepreneurs request compensation for their exposure to idiosyncratic risk (Mueller, 2011). Thus, the idea that entrepreneurs 'do not understand' idiosyncratic risk can be ruled out. Others refer to non-pecuniary benefits, such as entrepreneurs obtaining substantial rewards from being 'their own boss', and thus they are willing to accept a sub-optimal risk-return trade-off (Blanchflower and Oswald, 1998; Hamilton, 2000; Benz and Frey, 2008; Ødegaard, 2009; Shefrin, 2011; Puri and Robinson, 2013).

Another perspective is that the bond between entrepreneur and firm is like the familial tie between parent and child. Venture stimuli influence reward systems and mental factors associated with judgment (Lahti et al., 2019).

An additional view suggests that entrepreneurs may invest in what is familiar to them, displaying ambiguity aversion (Gutierrez *et al*., 2020)[2]. Entrepreneurs may therefore be willing to invest more in their firms if they perceive such investment as being safer and less ambiguous than external options such as the market (Welter *et al*., 2016).[3]

According to behavioral finance literature, overconfidence and over-optimism help explain why entrepreneurs often overinvest in their companies. More generally, these biases may explain why people decide to become entrepreneurs. People tend to be overconfident about their career, given they chose such an occupation. Overconfidence is higher in professions where ability estimates are noiser, like entrepreneurship (Lazear, 2016).

Previous studies have often focused separately either on overconfidence or over-optimism. Research on overconfidence (e.g., Camerer and Lovallo, 1999; Arabsheibani *et al.*, 2000) shows that it may generate excess entry into the market. This excess entry is probably due to overestimating skills and probability of success or underestimating risk. Studies on optimism show that entrepreneurs seem to be especially prone to over-optimism (Dosi and Lovallo, 1997; Arabsheibani *et al.*, 2000; Parker, 2009, 2012) and that optimism is significantly and positively associated with the propensity to become an entrepreneur (Åstebro, 2003; Coelho *et al.*, 2004).

[2] Vardas and Xepapadeas (2015) show that investors facing ambiguity and following optimal robust portfolio rules increase the asset holdings for which there is less ambiguity, providing an additional explanation for the home bias puzzle.

[3] Although capital rationing may explain a greater use of personal funds by entrepreneurs, it does not explain why some entrepreneurs invest too much in their firms. If capital rationing implies an excessive use of personal funds and a suboptimal risk-return trade-off, entrepreneurs should choose not to invest in their company and instead invest their available funds in a well-diversified portfolio.

A more comprehensive approach proposed by Chen *et al.* (2018) claims that this large consensus in attributing excess of entry only to behavioral biases is, at least, premature. They present a model that shows how entry and exit mechanisms, apparently driven by behavioral biases, might instead be displayed by rational Bayesian entrepreneurs and thus just *appear* to be irrational to an external observer. At the same time, comparing unbiased and biased entrepreneurs, the authors also show the distinct effects of overconfidence and over-optimism.

Comparing psychological and behavioral finance literature is crucial in order to discern how behavioral biases impact entrepreneurs' decisions. Doing so would allow alignment of sometimes different definitions of overconfidence and over-optimism, therefore avoiding any misunderstanding due to terminology.

The psychological literature proposes various definitions of overconfidence (e.g., Fischhoff *et al.*,1977; Moore and Healy, 2008). In particular, Moore and Healy (2008) identify three types of overconfidence: (i) overestimation about one's actual ability, performance, level of control, or chance of success; (ii) overplacement, which occurs when one believes to be better than others; (iii) overprecision, which is excessive certainty regarding the accuracy of one's beliefs.

The behavioral finance literature usually distinguishes between 'overconfidence about ability' and 'overconfidence about knowledge or beliefs' (Shefrin, 2005). The former occurs when people believe they are (or can do) better than they actually are (or can do); the latter when they think they know more than they actually know. Thus, 'overconfidence about ability' refers to overestimation and overplacement. 'Overconfidence about knowledge and beliefs' refers to overprecision.[4] The latter characteristic is thought to lead to risk underestimation (Shefrin, 2005).

[4] Huang *et al*. (2017) suggest this perspective in their helpful review and comparison of the behavioral finance and psychological literature.

While this connection between risk underestimation and 'overconfidence about knowledge and beliefs' is taken for granted in the behavioral finance literature, it is not so in psychology. Thus, it is worth further clarifying the point; excessive certainty regarding the accuracy of one's knowledge or beliefs leads to placing intervals which are too narrow in estimating future outcomes. Since estimation intervals are connected to standard deviation, the thinner the interval, the lower the expected volatility.

A parallel strand of literature studied overconfidence in managerial decisions. Malmendier and Tate (2005) claim that CEOs' over-investment in their company's stock is enough to indicate overconfidence. Their work is informative for the entrepreneurial sphere, even if some aspects do not directly apply in this case. On the one hand, CEOs' overconfidence might resemble that of the entrepreneurs concerning overestimation and overplacement. CEOs share with entrepreneurs the potential adverse effects of under-diversification and exposure to the idiosyncratic risk of their company: their compensation comes from the same company where they invest their human capital. Thus, bad outcomes will negatively impact their wealth and reduce their external employment opportunities. On the other hand, unlike entrepreneurs, CEOs are often remunerated with stock option plans. This gives CEOs the incentive to increase their assets' volatility, raising the value of their stock options (Malmendier and Tate, 2005). Thus, CEOs must trade off the costs of under-diversification against the value of holding stock options. Overconfidence leads them to overestimate their degree of control over future returns, inducing them to postpone option exercise. Malmendier and Tate (2005) base their theory on CEOs' skill overestimation and self-attribution rather than overprecision. The authors recognize that their argument may not hold in the case of CEOs overestimating their beliefs' precision because miscalibration reduces the expected stock volatility, lowering the value of stock options.

Huang *et al*. (2017) claim that overconfidence (referring to overestimation and over-placement) and over-optimism have been used almost interchangeably in previous studies. Yet, they are different constructs and should be treated accordingly. Shefrin (2005) stresses the difference between overconfidence and excessive optimism, noting that while the two biases are linked, they are not the same: one can be a pessimist and simultaneously overconfident. Åstebro *et al.* (2007) reinforce this perspective, noting that optimism is a global construct (a general feeling that good things will happen in life), while overconfidence has a greater individual dimension (self-perceived ability and knowledge).

Regarding over-optimism, the definitions of the behavioral finance and psychological literature are closer than those used for overconfidence. 'Excessive optimism' is viewed as the tendency to overestimate the frequency of good outcomes and underestimate that of bad ones (Shefrin, 2005).

By over-optimism, we refer to 'unrealistic optimism' as a domain-specific bias in expectations (Weinstein, 1980), rather than to 'dispositional optimism', the positive personality trait by which a person holds positive generalized expectations regarding the future (Scheier and Carver, 1985).[5]

While it is necessary to consider both overconfidence and over-optimism, it is not enough to do so separately. We share the belief that an entrepreneurship model should consider both biases simultaneously (Chen *et al*., 2008). In the following section, we propose our theoretical model that goes precisely in this direction.

[5] We could have call it just 'optimism,' defining 'over-optimism' as the situation in which the entrepreneur registers excessive levels of it. Still, we are stressing the difference between the two psychological constructs of dispositional optimism and unrealistic optimism.

Theoretical setup

We develop a model that aims to explain how overconfidence and over-optimism may lead the owners of private businesses (entrepreneurs, according to Levine and Rubinstein, 2017) to invest a large share of their personal wealth in their own companies, rather than pursuing 'rational' portfolio diversification strategies.[6]

We consider entrepreneurs who need to choose which part of their wealth to invest in their firm and which part to invest in the risk-free asset and the stock market. The portfolio optimization problem is dual: either the entrepreneurs minimize the risk for a given portfolio expected return or maximize the return for a given portfolio risk (Ingersoll, 1987).

We acknowledge that both overconfidence and over-optimism may simultaneously affect the entrepreneurs' expectations on the distribution of future outcomes. This distribution can be considered part of a single process that maps future states to risk-adjusted rewards. In our model, we let overconfidence negatively impact an entrepreneur's perception of her private company risk (Simon *et al.*, 2000). We allow over-optimism to positively alter the perception of the private company's expected returns (de Meza and Southey, 1996).

In the following section, we discuss the impact of overconfidence on risk minimization. Then, we consider the effects of over-optimism on return maximization.

[6] This is what we mean by under-diversification, i.e., sub-optimal diversification. Of course, when entrepreneurs invest even a tiny part of their wealth in the risk-free asset or in the market portfolio, they are actually diversifying away part of the idiosyncratic risk associated with the investment in their private firms. However, we define under-diversification as the case of excessive investment in the private firm compared to the weight of total wealth that entrepreneurs should invest in their firms in an optimal situation.

Overconfidence-driven under-diversification

Consider an entrepreneur who holds a portfolio composed of two risky assets with weights $\boldsymbol{\omega} = [\omega_I, \omega_M]'$ and a risk-free asset with weight ω_F. I denotes the entrepreneur's investment in her firm, while M the entrepreneur's investment in a well-diversified stock market portfolio. The excess return of the entrepreneur's portfolio can be expressed by $\mu_P = \boldsymbol{\omega}'\boldsymbol{\mu}$, where $\boldsymbol{\mu} = [\mu_I, \mu_M]'$ is the vector of the excess returns over the risk-free rate r_F.

The portfolio variance is given by $\sigma_P^2 = \boldsymbol{\omega}'\boldsymbol{\Sigma}\boldsymbol{\omega}$, where $\boldsymbol{\Sigma} = \begin{bmatrix} \sigma_I^2 & \sigma_{IM} \\ \sigma_{IM} & \sigma_M^2 \end{bmatrix}$ represents the positive-definite variance-covariance matrix of the returns of risky assets with $det\,\boldsymbol{\Sigma} = \sigma_I^2\sigma_M^2 - \sigma_{IM}^2 > 0$.[7]

For a given value of portfolio expected excess return, $\mu_P = k$, the entrepreneur prefers the portfolio with the lowest variance. She faces the problem

$$\begin{cases} min\ \boldsymbol{\omega}'\boldsymbol{\Sigma}\boldsymbol{\omega} \\ \boldsymbol{\omega}'\boldsymbol{\mu} = k \end{cases} \tag{1}$$

Note that the constraint $\omega_I + \omega_M + \omega_F = 1$ is implicit in $\boldsymbol{\omega}'\boldsymbol{\mu} = k$.

Solving the problem (Pattitoni and Savioli, 2011), the optimal portfolio weights are

$$\boldsymbol{\omega}(k) = \frac{k\boldsymbol{\Sigma}^{-1}\boldsymbol{\mu}}{\boldsymbol{\mu}'\boldsymbol{\Sigma}^{-1}\boldsymbol{\mu}} \tag{2}$$

[7] Our assumption of a positive-definite variance-covariance matrix rules out the two extreme cases of correlation equal to 1 or -1 between the private company and the market portfolio. Not making this assumption would result in mathematical, economic, and practical problems and implications. From a mathematical perspective, 1 or -1 correlations would imply a non-invertible variance-covariance matrix. From an economic point of view, 1 or -1 correlations would imply the possibility of making debt at a risk-free rate to invest in a zero-risk portfolio with a potentially greater return than the risk-free asset. That would result in arbitrage opportunities, "money machines," and "free lunches." In practice, these extreme cases are not a real concern: in reality, it would be difficult to find a financial asset with a perfect positive or perfect negative correlation with a private firm.

The first element of $\boldsymbol{\omega}(k)$ represents the weight in the private company, namely

$$\begin{aligned}\omega_I(k) &= \frac{k(\sigma_M^2\mu_I - \rho_{IM}\sigma_I\sigma_M\mu_M)}{\sigma_M^2\mu_I^2 - 2\rho_{IM}\sigma_I\sigma_M\mu_I\mu_M + \sigma_I^2\mu_M^2} \\ &= \frac{k\sigma_M^2\alpha}{\sigma_M^2\mu_I^2 - 2\rho_{IM}\sigma_I\sigma_M\mu_I\mu_M + \sigma_I^2\mu_M^2}\end{aligned} \quad (3)$$

where $\rho_{IM} = \sigma_{IM}/(\sigma_I\sigma_M)$ and α is the Jensen's alpha, i.e., $\alpha = \mu_I - \rho_{IM}(\sigma_I/\sigma_M)\mu_M$.

As noted above, overconfidence causes the entrepreneur to undervalue her company's actual risk. In this case, the biased standard deviation of the company returns, indicated by $\tilde{\sigma}_I$,[8] is lower than the actual standard deviation, i.e., $\tilde{\sigma}_I < \sigma_I$.[9] We model $\tilde{\sigma}_I$ as

$$\tilde{\sigma}_I = \sigma_I(1 - \delta_C) \;\; \delta_C \in [0,1) \quad (4)$$

where δ_C is the overconfidence parameter, ranging from 0 (no overconfidence) to 1 (maximum overconfidence).[10] When δ_C tends to 1, then $\tilde{\sigma}_I$ tends to 0.

To analyze the impact on the portfolio weight in the private firm caused by overconfidence, we define $\tilde{\omega}_I(k)$ as $\omega_I(k)$ in Equation (3) with $\tilde{\sigma}_I$ in place of σ_I, that is with the biased standard deviation instead of the actual one, to consider that overconfident entrepreneurs tend to underestimate their companies' risk. We then define the overconfidence bias as

$$b_c = \tilde{\omega}_I(k) - \omega_I(k) \quad (5)$$

Furthermore, using the definition of $\tilde{\omega}_I(k)$, we get the partial derivative

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[8] From now on, the tilde over a symbol (e.g., $\tilde{\sigma}_I$) indicates a biased parameter or variable.

[9] Note that, since the covariance between the private company returns and the market returns is given by $\sigma_{IM} = \rho_{IM}\sigma_I\sigma_M$, if the perceived standard deviation of the company returns, $\tilde{\sigma}_I$, differs from the actual one, σ_I, then overconfidence leads to a biased perception of the covariance as well, $\tilde{\sigma}_{IM}$.

[10] Choosing $\delta_C \in (-\infty, 1)$, we would allow for underconfidence. Any alternative parameterization for $\tilde{\sigma}_I$ would lead to the same qualitative result provided that $\frac{\partial\tilde{\sigma}_I}{\partial\delta_C} < 0$. However, our parametrization is the one that allows reading the results in percentage terms (elasticities) of overconfidence.

$$\frac{\partial\widetilde{\omega}_I(k)}{\partial\delta_C}=\frac{k\sigma_I\sigma_M\mu_M\left[2\sigma_I(1-\delta_C)\sigma_M\mu_I\mu_M-\rho_{IM}\sigma_M^2\mu_I^2-\rho_{IM}\sigma_I^2(1-\delta_C)^2\mu_M^2\right]}{\left[\sigma_M^2\mu_I^2-2\rho_{IM}\sigma_I(1-\delta_C)\sigma_M\mu_I\mu_M+\sigma_I^2(1-\delta_C)^2\mu_M^2\right]^2} \tag{6}$$

Based on Equations (5) and (6), we can conveniently divide our analysis of the effect of overconfidence on the portfolio weight in the private company into three cases: first, the private company and market portfolio returns are uncorrelated; second, they are negatively correlated; third they are positively correlated. Assuming a null correlation between a private company and market portfolio returns is like assuming that the economic situation of the private company is (mostly) not affected by the economic contingency (Pattitoni *et al.*, 2013b). While not entirely realistic, this assumption might be plausible for new ventures operating in innovative industries and has the advantage of greatly simplifying the analysis. The main result when the private company and market returns are uncorrelated is that the overconfident entrepreneurs tend to overinvest in their company and to be under-diversified, $\partial\widetilde{\omega}_I(k)/\partial\delta_C > 0$ and $b_c > 0$. When the private company and market portfolio returns are negatively correlated (e.g., the private company operates in a countercyclical industry), then $\partial\widetilde{\omega}_I(k)/\partial\delta_C > 0$ as well. Therefore, it continues to hold that $b_c > 0$, i.e., the entrepreneur underestimates her company's risk and overinvest in it. Finally, when the private company and market portfolio returns are positively correlated (i.e., the private company operates in a cyclical industry), the sign of $\partial\widetilde{\omega}_I(k)/\partial\delta_C$ is not straightforward.

As we more precisely show in Appendix A (together with some additional results), while $\partial\widetilde{\omega}_I(k)/\partial\delta_C > 0$ continues to hold for the most part, there is an extreme case when the level of overconfidence is exceptionally high and $\partial\widetilde{\omega}_I(k)/\partial\delta_C < 0$. In this extreme case, the entrepreneur invests so much in her company that, to meet the constraints of the portfolio selection problem, the weight in the well-diversified market portfolio needs to be negative, i.e., she finances her investment in the company by selling the market portfolio short.

While theoretically possible, this risky strategy is uncommon in practice and is often subject to restrictions for non-professional investors like the one we consider. Furthermore, market equilibrium implies that not all investors can simultaneously short sell the market portfolio to finance their activities. This extreme case becomes less relevant when describing the behavior of the average entrepreneur, which entails no ambiguity on the sign of the derivative. We may thus conclude that, even when $\rho_{IM} > 0$, overconfidence leads to overinvestment in the entrepreneur's own company and to portfolio under-diversification, $b_c > 0$.

All the results discussed so far describe the effects of under evaluating the actual risk due to overconfidence and are summed up in the following observation.

Observation 1. Typically, overconfidence leads the entrepreneur to overinvest in her company and to under-diversify her portfolio, $\partial\widetilde{\omega}_I(k)/\partial\delta_C > 0$ and $b_c > 0$.

From the previous observation, a first testable hypothesis follows.

H1. The entrepreneur's investment in her company positively correlates with her level of overconfidence.

Over-optimism-driven under-diversification

Since overconfidence affects risk perception, we studied its effect on portfolio risk using a risk minimization approach and keeping the expected return level fixed. In what follows, we analyze the impact of over-optimism on portfolio expected return using a return maximization approach, which holds the objective risk constant. Figure 1 shows the duality of the problem showing the tangency conditions that identify lower iso-risk (left plot) and upper iso-return (right plot).

[Insert Figure 1 about here]

The duality of the problem allows considering return maximization as the solution for the entrepreneur's optimization problem for a given value of portfolio risk, $\sigma_P^2 = s^2$. In such a setting, the entrepreneur faces the problem

$$\begin{cases} max\, \boldsymbol{\omega}'\boldsymbol{\mu} \\ \boldsymbol{\omega}'\boldsymbol{\Sigma}\boldsymbol{\omega} = s^2 \end{cases} \tag{7}$$

Solving the problem, the optimal portfolio weights are[11]

$$\boldsymbol{\omega}(s) = \frac{s\boldsymbol{\Sigma}^{-1}\boldsymbol{\mu}}{(\boldsymbol{\mu}'\boldsymbol{\Sigma}^{-1}\boldsymbol{\mu})^{\frac{1}{2}}} \tag{8}$$

The weight in the private company is

$$\begin{aligned} \omega_I(s) &= \frac{s(\sigma_M^2\mu_I - \sigma_{IM}\mu_M)}{[(\sigma_I^2\sigma_M^2 - \sigma_{IM}^2)(\sigma_M^2\mu_I^2 - 2\sigma_{IM}\mu_I\mu_M + \sigma_I^2\mu_M^2)]^{\frac{1}{2}}} \\ &= \frac{s\sigma_M^2\alpha}{[(\sigma_I^2\sigma_M^2 - \sigma_{IM}^2)(\sigma_M^2\mu_I^2 - 2\sigma_{IM}\mu_I\mu_M + \sigma_I^2\mu_M^2)]^{\frac{1}{2}}} \end{aligned} \tag{9}$$

As mentioned above, over-optimism causes the entrepreneur to overestimate the actual return of the investment in her company. In this case, the biased expected return, indicated by $\tilde{\mu}_I$, is larger than the actual expected return, i.e., $\tilde{\mu}_I > \mu_I$. We model $\tilde{\mu}_I$ as

$$\tilde{\mu}_I = \frac{\mu_I}{1 - \delta_O} \quad \delta_O \in [0,1) \tag{10}$$

where δ_O is the over-optimism parameter, which ranges from 0 (no over-optimism) to 1 (maximum over-optimism). When δ_O tends to 1, then $\tilde{\mu}_I$ tends to infinity.[12]

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[11] As the problem is quadratic, we also obtain a second solution with weights equal to minus those of Equation (10). We discard them since they are dominated ($\alpha > 0 \Rightarrow \omega_I(s) > 0$).

[12] Choosing $\delta_O \in (-\infty,\ 1)$, we would allow for pessimism as well. Any alternative parameterization for $\tilde{\mu}_I$ would lead to the same qualitative result provided that $\frac{\partial \tilde{\mu}_I}{\partial \delta_O} > 0$. However, our parametrization is the one that allows reading the results in percentage terms (elasticities) of over-optimism.

Note that the justifications of the entrepreneur's under-diversification based on non-pecuniary benefits as the desire for control (Shefrin, 2011) can be modeled by varying μ_I as well. In that case, the 'biased' μ_I would incorporate, after a suitable normalization, the value of non-pecuniary benefits. Therefore, our model can simultaneously consider the case of under-diversification brought about by over-optimism and/or non-pecuniary benefits.

To see the variation of the portfolio weight in her company in case of over-optimism, we define $\widetilde{\omega}_I(s)$ as the $\omega_I(s)$ in Equation (9) with $\tilde{\mu}_I$ in place of μ_I, to underline that over-optimistic entrepreneurs will overestimate future expected returns from their companies. Using this definition, we get the partial derivative

$$\frac{\partial \widetilde{\omega}_I(s)}{\partial \delta_O} = \frac{s \frac{\mu_I}{(1-\delta_O)^2} \mu_M^2 (\sigma_I^2 \sigma_M^2 - \sigma_{IM}^2)^{\frac{1}{2}}}{\left[\sigma_M^2 \frac{\mu_I^2}{(1-\delta_O)^2} - 2\sigma_{IM} \frac{\mu_I}{(1-\delta_O)} \mu_M + \sigma_I^2 \mu_M^2\right]^{\frac{3}{2}}} \tag{11}$$

Since $\partial \widetilde{\omega}_I(s)/\partial \delta_O > 0$, the over-optimistic entrepreneur tends to overinvest in her company and to be under-diversified. The over-optimism bias is

$$b_o = \widetilde{\omega}_I(s) - \omega_I(s) > 0 \tag{12}$$

While in Appendix A, we analyze the effect of over-optimism more in-depth and present additional analyses, the results presented so far allow us to make the following observation.

Observation 2. Over-optimism leads to overinvestment in the entrepreneur's own company, $\partial \widetilde{\omega}_I(s)/\partial \delta_O > 0$, and to portfolio under-diversification.

From the previous observation, a second testable hypothesis follows.

H2. The entrepreneur's investment in her company positively correlates with her level of over-optimism.

Implicit overconfidence and over-optimism levels

To understand the effects of overconfidence and over-optimism on the weight invested by the entrepreneur in her company, we consider a numerical example. We choose parameters following a simple set of economic and financial assumptions: the private investment is riskier than the market; the private investment is mildly procyclical; the expected return from the private investment is greater than the market. More specifically, we use the following set of parameters to respect our assumptions: $\sigma_I = 0.40$, $\sigma_M = 0.20$, $\rho_{IM} = 0.20$, $\mu_I = 0.15$, $\mu_M = 0.06$. Furthermore, we set $k = 0.12$ and implicitly determine $s = 0.273$.

Based on this set of parameters, in Table 1, we show how varying the level of overconfidence (Panel A) or the level of over-optimism (Panel B) impacts $\widetilde{\omega}_I$.

[Insert Table 1 about here]

For moderate levels of overconfidence, an increase in δ_C leads to an increase in $\widetilde{\omega}_I$. Note that even low levels of overconfidence cause a severe overinvestment in the private company (e.g., when $\delta_C = 0.2$, the weight in the private company is about 20% larger than it should be if the entrepreneur was not overconfident).[13]

When the level of overconfidence tends to its limiting value (i.e., $\delta_C \to 1$), then $\widetilde{\omega}_I = 0.8$. Considering the over-optimism bias, we note that an increase in δ_O always causes an increase in $\widetilde{\omega}_I$.

[13] This result comes from the comparison between the values assumed by $\widetilde{\omega}_I$ when δ_C varies. When $\delta_C = 0$, $\widetilde{\omega}_I = 0.509$. When $\delta_C = 0.2$, $\widetilde{\omega}_I = 0.605$. Then, the percentage change is 18.86%.

In this numerical example, overconfidence leads to higher overinvestment than over-optimism.[14]

We can also analyze Table 1 with a 'bottom-up' perspective to calculate the 'implicit' overconfidence and over-optimism levels given a set of parameters and an observed $\widetilde{\omega}_I$. For example, based on Table 1 – Panel A (i.e., using a risk minimization perspective with $k = 0.12$), after observing $\widetilde{\omega}_I = 0.696$, we can conclude that $\delta_C = 0.4$. Calculating the implicit levels of overconfidence and over-optimism is helpful to determine how these behavioral biases may affect entrepreneurial decisions. In fact, these biases and their magnitude impact the entrepreneurs' portfolio weight invested in their companies and, consequently, the level of idiosyncratic risk they bear due to sub-optimal decisions in portfolio formation. In Appendix B, we provide an additional numerical example based on a new set of parameters from Kerins *et al.* (2004), who analyzed a sample of IPOs in technologically oriented industries referred to companies going public before and during the Internet bubble. Results do not qualitatively change when using this new set of parameters. In addition, we produced several others analyses (not reported for brevity but available upon request). Our sensitivity analyses confirm that overconfidence dominates over over-optimism when excluding unplausible cases.

Empirical analysis

This section empirically tests H1 and H2 summarized in the previous section, using a Structural Equation Modelling (SEM) approach.

[14] We can prove this claim calculating the percentage change in $\widetilde{\omega}_I$ when δ_O varies and showing that is lower than the ones calculated above for δ_C.

The SEM approach is designed to deal with multivariate systems involving latent constructs.[15] In the following subsections, we describe our unique dataset and variables, then present our main results and robustness checks.

Sample and data

The dataset is obtained from the Italian Association of Insurance Firms (ANIA, *Associazione Nazionale fra le Imprese Assicuratrici*). In 2008-2009, ANIA gathered information on 2,295 Italian small and medium enterprises (SMEs) with fewer than 250 employees through a survey of small business owners (SBOs).[16] The average firm's age is 26 years (median 22 years), and while the distribution is somehow heterogeneous – 10% of firms are less than 5 years old, while another 10% of firms are more than 50 years old – we can consider these firms, on average, as mature. In terms of size, the sample comprises small firms, with a median value of revenues from sales of 2.4 million euros.[17] The survey was divided into a questionnaire and a direct interview. SBOs were first asked to fill in a questionnaire containing data on insurance coverage and other data related to their firm. Then, they were interviewed to gather additional (personal) information. Thus, a unique feature of this dataset is that it combines SBOs' personal information as well as more formal data on their companies. While questionnaires gathered data on the firms, the interviews were intended to collect SBOs' personal information. Some questions were intentionally designed to detect the SBOs' behavioral biases.

[15] Of course, measuring latent constructs is a complicated task and any empirical analysis involving latent constructs ultimately depends on the sample used and the available variables. However, our theoretical results would remain valid even if the empirical analysis suffered from identification problems.
[16] After deleting observations with missing values, and because we have partial access to the original dataset that is proprietary, we end up with 1,613 firms in our sample. Partial access to the database means that we do not have available all the variables included in the original dataset. For example, we lack detailed information on firms' age and size. To alleviate this shortcoming, we have taken as much information as possible from an analysis that use the full proprietary dataset, Guiso and Schivardi (2017), that is very detailed with respect to all variables.
[17] The distribution is asymmetrical with an average of 18 million euros.

The dataset thus includes information on SBOs' behavioral biases, demographic characteristics, and data regarding their families, such as household wealth.[18]

Measurement Variables and Descriptive Statistics

This section only presents the economic rationale of the variables we use in our empirical analysis. Table 2 provides a complete and detailed description of their construction.

[Insert Table 2 about here]

The survey from which we constructed our database intentionally included questions to account for overconfidence, using well-known variables from the behavioral finance literature.

The first variable, BTA ('Better-than-Average' effect), was designed to identify overplacement. It is one of the variables mostly used in literature to measure overconfidence (Alicke, 1985; Alicke *et al*., 1995; Kruger, 1999; Alicke and Govorun, 2005). As Moore and Schatz (2017, p. 4) state: ‘The evidence for "better-than-average" beliefs is so voluminous that it has led several researchers to conclude that overplacement is nearly universal.’[19]

The other four variables usually refer to overconfidence in general and are often not explicitly related to overestimation, overplacement, or overprecision. The variable *Male* identifies male SBOs. This variable aims at capturing the well-known evidence that men tend to be more overconfident than women (Barber and Odean, 2001; Hansemark, 2003). Gender differences in overconfidence appear to be task-dependent (Lundeberg *et al.*, 1994) and higher in activities typically perceived to be in the masculine domains (Deaux and Emswiller, 1974; Deaux and Farris, 1977; Lenney, 1977; Beyer and Bowden, 1997; Bonte and Piegeler, 2013). Since

[18] Respondents had no incentive to answer untruthfully to the survey; all the data were gathered anonymously, so there were no concerns to misreport sensitive data (e.g., personal wealth) due to tax or insurance concerns.
[19] However, Moore and Schatz (2017) claim that this conclusion may be not well-grounded. See the discussion that follows and Table 2 for details on how we measure BTA and the other variables used in the empirical analysis.

entrepreneurship is perceived as a masculine domain, we expect men to be more overconfident than women among entrepreneurs. Barber and Odean (2001, p. 262) affirm that: ‘Psychologists find that men are more overconfident in areas such as finance than women.’ They show that male investors tend to be more aggressive, take more risks, and trade more than female investors. Huang and Kisgen (2013) find that male executives issue debt more often, undertake more acquisitions, place narrower bounds on earnings estimates, and are more likely to exercise stock options later than female executives. So, they suggest men are more overconfident in critical corporate decisions than women. Graham *et al*. (2013) find that male CEOs tend to run companies with higher debt ratios than female CEOs. Faccio *et al.* (2016) find that firms run by female CEOs have lower leverage, less volatile earnings, and lower corporate risk-taking than similar companies run by male CEOs.

Height measure SBOs' height with the explicit aim of identifying its link with overconfidence. Stature appears to be so relevant in several fields. The literature coined the term 'height gap,' referring to the evidence that taller individuals get higher wages, higher profits, better jobs and are in general happier than shorter individuals (e.g., Persico *et al.*, 2004; Case and Paxson, 2008; Case *et al*., 2009; Deaton and Arora, 2009). The 'height-wage disparity' is about the same magnitude as the 'gender-wage disparity' (Persico *et al.*, 2004; Deaton and Arora, 2009). A possible explanation for this evidence is that height is essential in developing confidence, especially in the adolescent years, which may translate into wage disparity.[20] This literature suggests that height is a reasonable measure for overconfidence. As claimed by Graham et al. (2013), taller and younger overconfident CEOs tend to take more risks and are more likely to run growth companies.

[20] An alternative explanation is that height proxies for cognitive ability (Case and Paxson, 2008; Case *et al*., 2009).

Overconfidence may also increase ambition, morale, persistence, and resolve (Johnson and Fowler, 2011; Bernoster *et al*., 2018). In particular, overestimation seems to occur when one overestimates how quickly one will get work done, committing to more than one can humanly accomplish (Moore, 2020). The number of hours worked is used by Bitler *et al*. (2005) to measure effort. Everett and Fairchild (2015) suggest using the entrepreneurial level of effort – or alternatively changes in the level of effort – as a proxy for overconfidence. They state: 'Regardless, it is intuitively clear that an entrepreneur will only expend effort on the enterprise if he is confident that his effort will positively impact the enterprise's probability of success. Otherwise he would be knowingly wasting effort.' (Everett and Fairchild, 2015, p. 6-7). In this respect, the survey contained a question asking SBOs the number of hours after which they stated they would stop working to do something else. Thus, we have the number of hours worked by the entrepreneurs and after how many hours they would stop working and do something else. The related variable *Dedication* is a measure of how the entrepreneurs are dedicated to their firm (Salanova *et al.*, 2001; Schaufeli *et al.*, 2002) and 'is characterized by a sense of significance, enthusiasm, inspiration, pride, and challenge.' (Schaufeli *et al.* 2002, p. 74).

Åstebro *et al.* (2007) analyze inventors' perseverance after being told to quit, finding a positive role for optimism, while overconfidence seems to have no effect. However, as the authors recognize, that is an unexpected result given the large body of literature reporting a significant overconfidence effect. They refer to two general types of overconfidence found in previous studies (Burson *et al.*, 2006; Kruger, 1999; Kruger and Dunning, 1999; Yates, 1990), calling them 'confidence in judgment' ('overconfidence in knowledge and beliefs' in Shefrin, 2005; 'overprecision' in Moore and Healy, 2008) and 'confidence in ability' (like in Shefrin, 2005; 'overestimation and overplacement' in Moore and Healy, 2008). Åstebro *et al.* (2007) claim to measure only the former, stating that: 'However, it may be the second type of overconfidence that causes inventors to move forward with their inventions after being advised to stop. If this is the case, our measure would not capture it.' In our survey, SBOs were asked to answer a question (see Table 2 for details) to measure *Perseverance*, the 'never give up' attitude. This measure seems to account for what Åstebro *et al.* (2007) call 'confidence in ability' (i.e., overestimation and overplacement). However, we do not exclude that, boosting their illusion of control, this measure may also be related to overprecision, affecting SBO perceptions of their chances of success and potentially leading them to underestimate risk.

The four variables we use to measure over-optimism are based on well-known characteristics in the literature.

The first variable, the so-called 'Rose-Colored Glasses,' measures dispositional optimism (Lovallo and Kahneman, 2003; Dawson and Henley, 2012). It is based on a question inserted on purpose into the survey, asking SBOs if they expected good things in life will happen to them with greater probability than bad ones.

The other three variables measure unrealistic optimism. As Hoelzl and Rustichini (2005, p. 305) point out: 'Unrealistic optimism seems a robust behavioural feature when people have to evaluate their own risk to become victims of unfortunate life-events, compared to the average population.' See Perloff and Fetzer (1986) and Hoorens and Buunk (1993). In this respect, the first two variables used to measure unrealistic optimism are based on two questions inserted in the survey to measure 'comparative optimism' (Weinstein, 1980), i.e., the belief that one is more likely to experience positive events than others.[21]

[21] Moore and Healy (2008) point out that Weinstein (1980) asked participants about positive common events and rare negative ones. While both event commonness and valence influence judgments of comparative likelihood, the effect of commonness is much higher the size of valence. In our survey, the question regarding future positive or negative events was generic, simply asking SBOs if they expected more good things than bad things in life, not referring to specific ones, thus avoiding the possible influence of higher or lower commonness.

The two questions asked SBOs their subjective perception of the chance of incurring accidents or causing damages compared to the average of other SBOs in the same industry. Instead, the third variable refers to the evidence that unrealistic optimism, as a judgmental bias, distorts decisions and leads to faulty assessments and sub-optimal outcomes. Quoting de Meza and Dawson (2021, p. 541): 'Faulty assessments do not only result in systematic decision errors, but also lead to rash behavior (de Meza *et al*., 2019) and inadequate precautionary measures.' See Dillard *et al*. (2009). In this regard, Armor and Taylor (1998, p. 332) suggest that: 'People who do not expect negative events to happen to them or who do not expect negative consequences to befall their actions may put themselves in actual danger (e.g., by not taking the necessary precautions).' Following this literature, the survey included a question asking SBOs if they set aside funds for possible future emergencies. ANIA, the Italian national association of insurance companies that administered the survey, was particularly interested in comparing this information to the insurance level of SMEs in Italy. Insurance contracts may be used as a substitute for emergency funds. However, firms in our sample are poorly insured.[22] Thus, the evidence that less than 30% of the SBOs set aside precautionary funds to face these negative events (accidents and damages) suggests that not having emergency funds may be a good proxy for unrealistic optimism (Guiso and Schivardi, 2017).

In Table 3, we present the descriptive statistics of these variables.

[Insert Table 3 about here]

The dependent variable in our models, omega (ω), measures the share (or weight) of the SBOs' own wealth invested in their companies. The SBOs' wealth is defined as the total sum invested in their private firms, risk-free assets, and the stock market. On average, the SBOs in our sample invest almost half (47.9%) of their total wealth in their company. This figure is in line with

[22] We do not report here data on firm insurance in our sample. For details, see Guiso and Schivardi (2017).

those found in other countries in previous studies in the literature. For example, Moskowitz and Vissing-Jørgensen (2002) show that, in their US sample, the average household invests 41% of its wealth (45% when weighting by net worth) in private equity and that 75% of all private equity was held by households with 50% or more of their wealth invested in a single company. Having such a large share of their personal wealth in their private company may lead SBOs to bear too much idiosyncratic risk that eventually may be transferred to their household and affect their wealth.

Our empirical models include several variables that may influence omega (ω). First, we consider variables that indicate whether the company has branches abroad, the region, and the company's sector. They are specifically meant to proxy for risk-return variables (correlations, volatilities, expected returns) that are unobservable for private companies but geographic- and sector-specific. With overconfidence and over-optimism, these variables should influence omega (ω). Like other studies (e.g., Pattitoni *et al.*, 2013a), the implicit assumption is that Italian firms within the same region-industry cluster share similarities in risk-return characteristics. In our sample, most companies have no branches abroad. This is expected since most firms among our SME sample are small. The most represented regions are Lombardy and Emilia Romagna, two of Italy's most productive regions, accounting for 16.4% of the firms in the sample. The most represented sectors are manufacturing (30.6%) and trade, hotels and restaurants (25.5%). In this respect, our sample represents the Italian reality where manufacturing and tourism services are prominent among SMEs.

Then, we built a variable measuring SBOs' attitudes toward risk using answers to a specific question asked during the interview with the SBOs. SBOs were asked which one of the following four states of the world they would prefer: 'Very high profits with a really high risk of loss,' 'Good profits and high risk of loss,' 'Normal profits with low risk of loss,' and, finally, ‘Low profits with no risk of loss.’ More than half of SBOs preferred ‘Normal profit, with low risk of loss.’ More than a third choose ‘Good profit, and high risk of loss,’ while only about 10% of SBOs admitted choosing ‘Low profit, no risk of loss.’ We acknowledge that responses to this question may be influenced by the fact that the survey was conducted between 2008 and 2009, during the first years of the global financial crisis.

Table 4 presents the correlations between omega (ω) and the main variables used.

[Insert Table 4 about here]

This simple correlation analysis shows that companies without branches abroad are financed with higher percentages of an entrepreneur's own wealth. Omega (ω) is not so significantly correlated with the measures of our two latent constructs. This result may be due to noise, and suggests using an SEM approach (more on this later) to partial out this noise from the proxy variables and extract the signal underlying the two common latent constructs. Finally, we find indirect support of our choices of the variables used to measure overconfidence and over-optimism. Entrepreneurs’ risk attitude is positively correlated with the overconfidence measures and negatively with the over-optimism ones. The measures of overconfidence and over-optimism are mainly positively related, as expected. Finally, we know that a measure could correlate to more than one latent variable. In contrast with a simple OLS approach based on proxy variables, the measurement part of an SEM extracts only the 'part' correlated with the latent construct of interest from each measure. So, the SEM estimation methodology takes care of the situation when a measure residually influences other latent variables.

Results

Our empirical models aim at estimating the relationship between the fraction of SBOs' wealth invested in their companies, overconfidence and over-optimism.

While we can observe omega (ω), that is the fraction of SBOs' wealth invested in their firms, both overconfidence and over-optimism are latent variables. We use a Structural Equation Modelling (SEM) approach to address the relationship between observable and latent variables.

SEMs are statistical tools specially designed to study structural relationships involving both observable and latent variables. A typical SEM framework can be divided into two parts: (i) a structural part, which accounts for the relationship between endogenous (with an equation for each) and exogenous variables (both of which can be observable or latent); and (ii) a measurement part, aimed at measuring latent variables. Results of SEM analyses are typically represented with path diagrams. Figure 2 shows the standardized coefficients of our path diagram.

[Insert Figure 2 about here]

In the upper part of the figure, we show the structural relationships between omega (ω), latent, and control variables. In the lower part, we measure overconfidence and over-optimism. In the measurement part of the model, all loadings on our latent variables, enclosed in ovals, are significant.

Height and *Male* (i.e., gender) are the variables that seem to better proxy for overconfidence, with statistically significant standardized coefficients equal to, respectively, 0.81 and 0.79, in line with the previous finding in the literature that suggest that the magnitude of 'height gap' is like the one associated with the 'gender gap' (Graham *et al*., 2013).[23] *BTA* is the third most significant variable with a coefficient of 0.15, followed by *Dedication* (0.14) and *Perseverance* (0.11).[24] A possible explanation of this evidence is that, while some previous studies associate

[23] For this reason, we eventually decided to insert both *height* and *male* separately in model 5 in Table 5, dedicated to robustness checks. We find that only the latter variable appears to be statistically significant.
[24] As a further robustness check, we also considered BTA separately in an OLS regression, finding that, considered alone, it is not statistically significant and reinforcing our finding that considering together all the variables

them with overplacement, stature and gender may also be associated with overprecision. Odean (1998) shows that overconfident investors who believe that the precision of their knowledge about the value of securities is greater than it actually is (i.e., overprecision) trade more than rational investors. Barber and Odean (2001) associate *gender* with overprecision since men are more overconfident and trade more than women.

Another possible explanation refers to the inconsistency of some studies on overconfidence (Moore and Healy, 2008). Findings of overestimation focused on complex tasks (Fischhoff *et al*., 1977; Hoffrage, 2004; Campbell *et al*., 2004), while findings of overplacement focused on easier tasks (Svenson, 1981). Studies on easy tasks seem to produce the most underestimation and overplacement. Studies on hard tasks produce the most overestimation, but also the most underplacement (Moore and Healy, 2008; Moore and Small, 2007, 2008). In this regard, we do not actually find evidence of underplacement among our survey respondents since we find the coefficient associated with *BTA* to be positive and statistically significant. However, its role in measuring overconfidence, as expressed by the magnitude of its coefficient, is smaller compared to *Gender* and *Height*. Furthermore, it is worth stressing that, as mentioned above, asking in a face-to-face interview if one believes to be above average may distort answers. It could also be the case that, in a difficult domain such as entrepreneurship, overestimation (mainly proxied by *Gender* and *Height*) may count more than overplacement (*BTA*).

We underline that all five variables considered in our SEM to measure overconfidence are significant. Thus, they appear to be related to this latent variable. We do not dismiss measures of overestimation and overplacement that may also be measures for overprecision. In this respect, Chen *et al*. (2008, p. 1005) observe 'that selection into the market generates a positive

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designed *ex ante* in the survey to measure overconfidence yields instead significant results. To save space we do not report this evidence here, that however is available upon request.

correlation across the population between overestimation (optimism) and overprecision at the individual level.'

In the same vein, all four variables used to measure over-optimism are statistically significant. Regarding the magnitude of coefficients, the variables *Accidents* and *Damages* record higher standardized coefficients in our SEM, equal, respectively, to 0.76 and 0.74. At the same time, *RCG* ranks only third in magnitude, with a coefficient of 0.57. A possible explanation of this evidence is that while *RCG* contributes to measuring our latent variable 'over-optimism,' it usually detects dispositional optimism rather than unrealistic optimism.[25] Instead, the variables *Accidents* and *Damages* were intentionally inserted in the survey as 'comparative optimism' measures. Our evidence shows that they seem to better measure over-optimism. In addition, the magnitude of their coefficients is very similar, suggesting that they are indeed similar in measuring 'comparative optimism' relative to other SBOs.

Finally, while positive and statistically significant, the variable *Emergencies Funds*, with a coefficient of 0.13, is the measure least related to our latent variable of over-optimism. Indeed, not setting aside additional funds in case of emergencies may also be due to other reasons, such as cash shortage, a problem that often arises among small and medium enterprises. As far as the measurement part of our SEM is concerned, we stress that all variables considered in measuring overconfidence and over-optimism are statistically significant, suggesting that they all contribute to increasing the precision in measuring the two latent variables.

In the structural part, we find evidence supporting H1 as the effect of overconfidence on omega (ω) is positive and highly significant. However, in contrast with H2, over-optimism seems not to significantly affect the weight in the entrepreneur's own firm. Consistent with the findings

[25] We underline that RCG was measured just using a generic question (see Table 2), not eliciting optimism using more specific questions including different types of events among which entrepreneurs could express their degree of optimism. This may have lowered the significance of this measure.

of our numerical example, this result suggests that the effect of overconfidence on omega (ω) is stronger than the effect of over-optimism. We recognize that our evidence may depend on our particular sample, including primarily mature firms. SBOs of mature firms, knowing past returns, can be well-calibrated and not over-optimistic in estimating future returns. Instead, despite experience, overconfidence may still play a role for these SBOs. This result aligns with previous studies showing that experience fuels overconfidence rather than accuracy (Oskamp, 1965). This evidence has been found in several fields. Experienced investors seem to overestimate their stock selection ability (Torngren and Montgomery, 2004). Entrepreneurs with greater experience display stronger confidence in the likelihood of success (Pryor *et al.*, 2016; Uygur and Kim, 2016). Entrepreneurs dynamically learn over time, but mostly how not to be over-optimistic, while overconfidence appears to be more harmful, last longer, and not to be eliminated by learning (Chen *et al.*, 2018). Thus, the predominant finding in literature that, *vis-á-vis* the accumulation of experience and judgment, entrepreneurs tend to invest a large share of their wealth in their companies suggests a major role for overconfidence (Heaton and Lucas, 2000; Moskowitz and Vissing-Jørgensen, 2002; Bitler *et al.*, 2005; Mueller, 2011; Kartashova, 2014).

Another important finding of our SEM is that the estimated covariance between our latent constructs, represented by a curved line in the figure, is not significant, suggesting that the two behavioral biases are different in nature. This finding confirms one of the main objectives of this paper, which is to clearly distinguish between overconfidence and over-optimism while considering the distinct (but also potentially simultaneous) effect of the two latent variables.

As for the control variables, we find significant regional and industry effects (in the figure, we report joint tests of significance). This is an expected result since, as we mentioned above, these variables measure omitted variables that affect SBOs' choices and might be shared across geographic and sector clusters. In addition, we find that SBOs whose firms have no branches abroad invest more in their companies and that SBOs' risk attitude seems to negatively affect omega (ω). Both these latter results may appear counterintuitive. Companies with no branches abroad typically exhibit returns that are more correlated to the domestic market than those with branches abroad. Thus, SBOs should invest less in their companies if they do not have units abroad. However, our results make sense if interpreted using 'local home bias': SBOs perceive their companies as safer investments – or at least less ambiguous (Welter *et al*., 2016) – if they do business only in the domestic market. They perceive a business abroad as more ambiguous, uncertain, and riskier. Greater risk aversion should generally lead to lower investments in one's company, given the associated idiosyncratic risk. However, if SBOs perceive their business as safer, a lower risk attitude implies greater company shares.

To analyze the relationship between entrepreneurs' investment in their company and behavioral biases more in-depth, Figure 3 shows the geographical representation of the regional averages of omega (ω) (left plot), the predictions of overconfidence (central plot), and over-optimism (right plot) based on the model in Figure 2. Darker colors indicate higher values of the related variable. Spatial clustering characterizes our variables, possibly reflecting unobserved heterogeneity at the regional level. This unobserved heterogeneity is perhaps brought about by structural risk-return characteristics of the firms omitted in the model but controlled for by including regional and industry fixed effects.

[Insert Figure 3 about here]

When models include latent variables, using SEMs is needed to improve the efficiency and overall precision of the results compared to simpler OLS models that use proxies. While SEM models are more efficient than OLS when dealing with structural relationships involving observable and latent variables, we have inserted some robustness checks using OLS. In OLS models, the variables meant to track overconfidence and over-optimism are included in the regression equation directly as proxies since there is no measurement part.[26] Table 5 presents robustness checks (we omitted the measurement part of the models for brevity).

[Insert Table 5 about here]

An initial concern with our empirical analysis is that overconfidence and over-optimism may be endogenous. Models 2, 3, and 4 take potential endogeneity into account with explicit equations for overconfidence and over-optimism. Model 2 allows omega (ω) to affect overconfidence and over-optimism. Thus, we consider potential simultaneity between the two biases and the share of the SBOs' own wealth invested in their company. Model 3 considers possible bi-directional feedback between overconfidence and over-optimism. In the model underlying Figure 2 (which is referred to in Table 5 as Model 1), we assumed and estimated the correlation between overconfidence and over-optimism. Instead, Model 3 assumes the relationship between the latter two biases to be structural. Model 4 considers both simultaneity and bidirectional feedback.

Results of Models 2, 3, and 4 suggest that the role of omega (ω) in modeling overconfidence and over-optimism is negligible (as the estimated effect is not significant). In addition, excluding Model 3, there are no significant coefficients to report in the overconfidence and over-optimism equations. After controlling for endogeneity and bidirectional feedback, some of the coefficients in the omega (ω) equation of Models 2, 3, and 4 become not significant. This effect is possibly due to inefficiency brought about by the inclusion of irrelevant paths (the standard errors of Models 2 and 3 seem to be inflated if compared to those of Model 1). Considering these results, we conclude that endogeneity is unlikely to play a significant role in

[26] Unreported results, available upon request, are qualitatively consistent with those of SEM models.

our empirical application or, at least, that its influence is not strong enough to invalidate inference based on simpler models.

A second point concerns the role of an entrepreneur's height and gender in the reflective measurement model of overconfidence. Since height and gender are exogenous variables, directly including these two variables among the determinants of omega (ω) rather than using them as reflective indicators may seem more appropriate. Model 5 provides such an empirical test; while male SBOs invest more in their companies, the effects of overconfidence and over-optimism on omega (ω) remain virtually unchanged.[27] This evidence seems to be in line with the idea that men are, on average, more overconfident than women (Barber and Odean, 2001), underestimating the riskiness of their firms. Similarly, it could be that male SBOs tend to take more risks, overinvesting in their private firms.

Furthermore, Models 6, 7, and 8 present sensitivity analyses excluding industry fixed effects (Model 6), regional fixed effects (Model 7), or both (Model 8). Our results confirm Model 1, suggesting that the relationship between behavioral biases and omega (ω) is robust enough to withstand changes in the model's specification.

Before concluding, we would like to stress that while we believe that our simple model can account for both overconfidence and over-optimism, the findings of the empirical analyses should, as usual, be considered with caution, depending on the specific sample on which the model is tested. Furthermore, since our sample is mainly constituted by mature firms, this feature may affect our findings. While for early-stage entrepreneurs, finely adjusting the proportion of wealth invested in their enterprise *versus* the financial market (i.e., the risk-free asset and the stock market) is unlikely to be possible, SBOs of mature firms know very well

[27] Further models control for education, measured in terms of school years. Results remain virtually unchanged and are not presented for brevity.

the (past) returns of their firm. They may have reliable information for forecasting future expected returns in a well-calibrated, less biased (or even unbiased) way. In other words, mature firms' SBOs, like the ones in our sample, are mainly (if not only) affected by overconfidence and less (or not) by over-optimism. The structural component of our SEM seems to support this interpretation. Testing our model on another sample, including younger, growing businesses, may yield different results. In this case, we could find that over-optimism may significantly impact the proportion of total wealth the entrepreneurs invests in their private firm. Therefore, we believe that our theoretical model could apply to both mature firms and younger ones, probably yielding different results in the empirical analyses, depending on the sample analyzed.[28]

Conclusions

Previous findings in relevant literature show that entrepreneurs tend to invest a large share of their personal wealth in their companies, bearing higher levels of idiosyncratic risk due to under-diversification. These higher levels of specific risk increase the cost of equity for entrepreneurs and reduce their firm value. Thus, exploring the causes of under-diversification contributes to the theoretical and academic debate and has practical implications.

We present a theoretical model that enables presentation and measurement of how overconfidence and over-optimism bias the perception of the first two moments of the distribution of the private company returns, leading entrepreneurs to invest a large share of their personal wealth in their firms.

Our model contributes to the literature on entrepreneurs' sub-optimal behavior in terms of under-diversification and overinvestment. This behavior may be partly due to behavioral biases

[28] We are grateful to an anonymous referee for having pointed out to us the importance of distinguishing between young and mature firms, and the need to stress why and how our model could still work for both.

and interpretation in the context of risk-return analyses. While we focus on overconfidence and over-optimism, our model encompasses motivations such as the desire for control. The latter, like over-optimism, is likely to lead entrepreneurs to perceive a higher expected return on their companies. In this case, the 'biased' firm expected return in our model would simply incorporate, after a suitable normalization, the value of non-pecuniary benefits. Our theoretical model uses a broad definition of overconfidence, even if it focuses on overprecision as the leading cause of entrepreneurs' risk underestimation. We do not reject the view that overestimation and overplacement can lead to overestimating the mean, together with over-optimism. Neither do we dismiss the possibility that overestimation and overplacement may contribute to risk underestimation. At the same time, we believe that overprecision is the more pervasive and persistent form of overconfidence.

Based on our theoretical model, we have created a numerical example to ascertain how much the entrepreneurs' decision to invest in their company is affected by variations in the two behavioral biases. The numerical example suggests that the effect of overconfidence is stronger than the effect of over-optimism. It can also be used to calculate the implicit levels of overconfidence and over-optimism after one observes the entrepreneur's weight invested in the private company. Being aware of the levels of overconfidence and over-optimism may be helpful for institutional investors such as venture capitalists when they choose which entrepreneurial projects to finance. It may also be beneficial for self-analyses by entrepreneurs to ascertain which proportion of their wealth is optimal to invest in their own firms.

Finally, using data on Italian SMEs and information on SBOs' behavioral biases and personal characteristics, we explore how overconfidence and over-optimism affect their choice of how much to invest in their companies. Using an SEM approach, our empirical results suggest that overconfidence indeed leads SBOs to invest more in their companies, while the effect of over-optimism is not statistically significant. Consistent with the findings of our numerical example, this result suggests the impact of overconfidence is stronger than the effect of over-optimism in determining the level of investment by SBOs, in a sample of mature SMEs.

Robustness checks corroborate our results and allow us to increase the generalization potential of our analysis.

Further empirical research could expand these results by considering asymmetric risk measures, such as the Value at Risk or the semi variance, to identify the effect of behavioral biases on downside risk perception. In addition, although Italy is an ideal context for our empirical analysis due to its entrepreneurial vocation, research on other countries could examine further implications of our theoretical model. These implications could be helpful to stimulate further debate about the effects of behavioral biases on entrepreneurial choices. Furthermore, other empirical analyses could try alternative measures of overconfidence and over-optimism and test the model on alternative samples.

A possible limitation of the present paper is that our sample is mainly constituted by mature firms. As we noticed, overconfidence may play a more significant role for these firms than over-optimism in explaining the SBOs' fraction of their total wealth invested in their private firm. Thus, it would be interesting to test the model on other samples that contain both mature and younger firms to test if the role of over-optimism remains negligible. We leave this additional test for future research.

Future research may also further investigate the conjunct effects of overconfidence and over-optimism using a dynamic framework like the one proposed in Chen *et al*. (2008), allowing for more effective investigation into how rational and behavioral reasons interact and explain entrepreneurial choices.

Appendix A

Sign of $\partial\widetilde{\omega}_I(k)/\partial\delta_C$ when $\rho_{IM} > 0$

As we noted in the subsection "Overconfidence-driven under-diversification," when the private company and market portfolio returns are positively correlated, the sign of $\partial\widetilde{\omega}_I(k)/\partial\delta_C$ is not straightforward. Imposing the condition $\partial\widetilde{\omega}_I(k)/\partial\delta_C = 0$, we find two stationary points. In the space $(\delta_C, \widetilde{\omega}_I)$, the coordinates of these two points are

$$
\begin{aligned}
(\delta_C^-, \widetilde{\omega}_I^-) &= \left(1 - \frac{\mu_I}{\mu_I - \alpha}\left(1 + \sqrt{1 - \rho_{IM}^2}\right), \frac{k}{2\mu_I}\frac{\rho_{IM}^2}{-\sqrt{1 - \rho_{IM}^2} - (1 - \rho_{IM}^2)}\right) \\
(\delta_C^+, \widetilde{\omega}_I^+) &= \left(1 - \frac{\mu_I}{\mu_I - \alpha}\left(1 - \sqrt{1 - \rho_{IM}^2}\right), \frac{k}{2\mu_I}\frac{\rho_{IM}^2}{\sqrt{1 - \rho_{IM}^2} - (1 - \rho_{IM}^2)}\right)
\end{aligned} \qquad \text{(A1)}
$$

Since $(\delta_C^-, \widetilde{\omega}_I^-)$ is a minimum and $(\delta_C^+, \widetilde{\omega}_I^+)$ is a maximum, $\partial\widetilde{\omega}_I(k)/\partial\delta_C > 0$ in the interval (δ_C^-, δ_C^+), and $\partial\widetilde{\omega}_I(k)/\partial\delta_C \leq 0$ elsewhere. We notice that $\alpha > 0$ is a sufficient condition for $\delta_C^- < 0$ to hold.[29] However, we assume $\delta_C \in [0,1)$. Thus, $\widetilde{\omega}_I$ reaches a minimum when $\delta_C = 0$ and $\widetilde{\omega}_I = \omega_I$. On the other hand, when overconfidence approaches its limiting value (i.e., $\delta_C \to 1$), we find a specific weight

$$
\lim_{\delta_C \to 1} \widetilde{\omega}_I(k) = \frac{k}{\mu_I} \qquad \text{(A2)}
$$

When $\delta_C \in (\delta_C^+, 1)$, $\partial\widetilde{\omega}_I(k)/\partial\delta_C < 0$. In this case, the entrepreneur invests so much in her company that, to meet the constraints of the portfolio selection problem, the weight in the well-diversified market portfolio needs to be negative,[30] i.e., she finances her investment in the

---

[29] $\alpha > 0$ is a prerequisite to justify investments in private companies because it can be interpreted as a positive Net Present Value (NPV > 0). If financial markets are efficient, then positive NPV investments are feasible only for real investment projects (e.g., investing in the entrepreneur's private company), and not for financial investment projects, for which the NPV should be 0.

[30] Using the constraint in the problem (1), we get $\widetilde{\omega}_M = (k - \widetilde{\omega}_I\mu_I)/\mu_M$. Therefore, when overconfidence reaches its limiting value and $\widetilde{\omega}_I(k) = k/\mu_I$, then $\widetilde{\omega}_M = 0$. When $\widetilde{\omega}_I(k) > k/\mu_I$, as it happens for $\delta_C \in (\delta_C^+, 1)$, then

company by selling the market portfolio short. This is indeed an unlikely situation in real-life applications. Figure A1 offers a graphical representation of these results.

[Insert Figure A1 about here]

Effect of overconfidence and over-optimism on portfolio risk and return

We offer some insights into the role of overconfidence and over-optimism in biasing the perception of an entrepreneur's portfolio risk and expected return. A point worth noting is that overconfidence implies suboptimal portfolio weights and a biased perception of portfolio risk. Since the perceived private company risk decreases with overconfidence (i.e., $\partial\tilde{\sigma}_I/\partial\delta_C = -\sigma_I < 0$), whenever the *perceived* portfolio risk increases with the *perceived* private company risk (i.e., $\partial\tilde{\sigma}_P/\partial\tilde{\sigma}_I > 0$) and overconfidence leads to overinvest in the company (i.e., $\partial\tilde{\omega}_I(k)/\partial\delta_C > 0$),[31] then it follows that $\partial\tilde{\omega}_I(k)/\partial\tilde{\sigma}_P = (\partial\tilde{\omega}_I(k)/\partial\delta_C)(\partial\delta_C/\partial\tilde{\sigma}_I)(\partial\tilde{\sigma}_I/\partial\tilde{\sigma}_P) < 0$.

Figure A2 shows the link between the perceived frontier of investments (the dashed line) and the weight in the entrepreneur's own company to clarify this result.

[Insert Figure A2 about here]

The first plot in Figure A2 shows the shift in the frontier caused by overconfidence, while the second one projects this shift in the private company weight. Note that the slope of the curve in the second plot is determined by $\partial\tilde{\omega}_I(k)/\partial\tilde{\sigma}_P$.

$\tilde{\omega}_M < 0$. Imposing $\tilde{\omega}_M \geq 0$ means that only corner solutions are possible, where the maximum weight that the overconfident entrepreneur may invest in her company is given by $\tilde{\omega}_I(k) = k/\mu_I$. Thus, the overconfident entrepreneur may even be frustrated by not being able, without short selling the market portfolio, to invest the desired amount of wealth in her private company.

[31] This is the most common case. Conversely, when $\rho_{IM} > 0$ and $\delta_C \in (\delta_C^+, 1)$ (i.e., when entrepreneurs should sell the market portfolio short), $\partial\tilde{\sigma}_P/\partial\tilde{\sigma}_I < 0$ but also $\partial\tilde{\omega}_I(k)/\partial\delta_C < 0$. Thus, the inequality $\partial\tilde{\omega}_I(k)/\partial\tilde{\sigma}_P < 0$ still holds.

Like overconfidence, similar reasoning applies to over-optimism. Over-optimism implies suboptimal portfolio weights and biased perception of portfolio returns. Since the *perceived* portfolio return increases with the perceived private company return (i.e., $\partial\tilde{\mu}_P/\partial\tilde{\mu}_I > 0$), the *perceived* private company return increases with the level of over-optimism (i.e., $\partial\tilde{\mu}_I/\partial\delta_O = \mu_I/(1-\delta_O)^2 > 0$), as well as the weight in the private company (i.e., $\partial\widetilde{\omega}_I(s)/\partial\delta_O > 0$).

Then, it follows that $\partial\widetilde{\omega}_I(s)/\partial\tilde{\mu}_p = (\partial\widetilde{\omega}_I(s)/\partial\delta_O)(\partial\delta_O/\partial\tilde{\mu}_I)(\partial\tilde{\mu}_I/\partial\tilde{\mu}_P) > 0$.

This result is clearly presented in Figure A3, which shows the link between the perceived frontier of investments (dashed) and the weight in the private company.

[Insert Figure A3 about here]

The plot on the right of Figure A3 shows the shift in the frontier caused by over-optimism; the plot on the left projects this shift on the private company weight. Note that the slope of the curve in the plot on the left is determined, as explained above, by $\partial\widetilde{\omega}_I(s)/\partial\tilde{\mu}_p$.

Appendix B

This Appendix considers an additional numerical example using Kerins *et al*. (2004) values. Kerins *et al.* (2004) analyze a sample of IPOs in technologically oriented industries referred to companies going public before and during the Internet bubble. Given the context, the values of both volatilities and expected returns are very high. Thus, this scenario may proxy for very 'good times' in the business cycle.

Using the estimates in tables 2 and 4 of Kerins *et al*. (2004), we get the following set of parameters: $\sigma_I = 1.204$, $\sigma_M = 0.162$, $\rho_{IM} = 0.195$, $\mu_I = 0.535$, and $\mu_M = 0.06$. We set $k = 0.300$ and implicitly determine $s = 0.566$. Based on this set of parameters, in Table A1, we show how varying the level of overconfidence (Panel A) or the level of over-optimism (Panel B) impact $\widetilde{\omega}_I$.

[Insert Table A1 about here]

Like the numerical example commented in the subsection "Implicit overconfidence and over-optimism levels," an increase in overconfidence leads to a rise in $\widetilde{\omega}_I$ and the same result applies when over-optimism increases (even if to a lesser extent).

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Tables and Figures

Table 1. Implicit overconfidence and over-optimism levels

Panel A – Overconfidence effects on risk minimization

δ_C	0.0	0.2	0.4	0.6	0.8	$\cong 1.0$
$\widetilde{\omega}_I$	0.509	0.605	0.696	0.768	0.805	0.800

Panel B – Over-optimism effects on return maximization

δ_O	0.0	0.2	0.4	0.6	0.8	$\cong 1.0$
$\widetilde{\omega}_I$	0.509	0.565	0.618	0.660	0.687	0.696

Parameters

k	s	μ_I	μ_M	σ_I	σ_M	ρ_{IM}
0.120	0.273	0.150	0.060	0.400	0.200	0.200

δ_C is the overconfidence parameter; δ_O is the over-optimism parameter; $\widetilde{\omega}_I$ is the biased portfolio weight in the private company; k is the given value of portfolio expected excess return; s is the given value of portfolio standard deviation; μ_I is the private company excess return over the risk-free rate; μ_M is the market portfolio excess return over the risk-free rate; σ_I is the private company standard deviation; σ_M is the market portfolio standard deviation; ρ_{IM} is the correlation between the private company returns and the market returns.

Table 2. Variable description

Variable		
Structural		
Omega (ω)	This variable, which can range from 0 to 1, indicates the share of the SBO's own wealth invested in her company. The SBO's wealth is defined as the sum of the investments in the company and in the financial market, i.e., in the risk-free asset and in the stock market portfolio.	
Domestic	This is a dummy variable equal to 1 when a company has no branches abroad.	
Regions	This is a set of regional dummies. Piedmont and Aosta Valley are pulled together since the latter is a small region geographically close to Piedmont.	
Industries	This is a set of dummies indicating the industry in which the SBO operates.	
Risk attitude	This is a measure of SBOs' attitude toward risk. SBOs were asked if they would prefer: (1) 'Low profits and no risk,' (2) 'Moderate profits and low risk,' (3) 'Good profits and moderate risk' or (4) 'Very high profits and risk.' The variable is normalized to the standard unit interval, with higher values indicating a greater attitude toward risk.	
Measurement		**References**
Dedication (log)	This is a measure of SBOs' dedication. It is measured as the natural logarithm of the number of hours after which the SBO states he would rather stop working to do something else.	Salanova *et al*. (2001); Schaufeli *et al*. (2002); Bitler *et al*. (2005); Johnson and Fowler, (2011); Everett and Fairchild (2015); Bernoster *et al*. (2018); Moore (2020).
Height (log)	Height is the natural logarithm of the SBO's height in centimeters.	Persico *et al*. (2004); Case and Paxson (2008); Case *et al*. (2009); Deaton and Arora (2009); Graham *et al*. (2013).
Male	This is a dummy variable equal to 1 for male SBOs.	Deaux and Emswiller (1974); Deaux and Farris (1977); Lenney (1977); Lundeberg *et al*. (1994); Beyer and Bowden (1997); Barber and Odean (2001); Hansemark (2003); Bonte and Piegeler, 2013; Huang and Kisgen, 2013; Faccio *et al*. (2016).
Perseverance	This is a measure of SBOs' perseverance. SBOs were asked if, in difficult times, they: (0) 'immediately give up' or (10) 'never give up.' All responses between 0 and 10 were accepted. The variable is normalized to the standard unit interval, with higher values indicating greater perseverance.	Åstebro *et al*. (2007); Burson et al. (2006); Kruger and Dunning, (1999); Yates, (1990).
BTA	This variable measures the 'Better Than Average effect.' SBOs were asked if they perceive their abilities and knowledge to be above or below the average with respect to other SBOs. The variable is normalized to the standard unit interval, with higher values indicating SBOs more confident in their abilities and knowledge.	Svenson (1981); Alicke (1985); Alicke *et al*. (1995); Kruger (1999); Alicke and Govorun (2005); Hoelzl and Rustichini (2005); Moore and Schatz (2017).
Accidents	This is a measure of the SBO's perception of the probability of having accidents. Higher values indicate that the SBO deems the probability of having accidents lower than the average of other SBOs operating in the same industry. The variable is normalized to the standard unit interval.	Weinstein (1980); Perloff and Fetzer (1986); Hoorens and Buunk (1993); Dawson (2017); Guiso and Schivardi (2017).
Damages	This is a measure of the SBO's perception of the probability of causing damages. Higher values indicate that the SBO deems the probability of causing damages lower than the average of other SBOs operating in the same industry. The variable is normalized to the standard unit interval.	Weinstein (1980); Perloff and Fetzer (1986); Hoorens and Buunk (1993); Dawson (2017); Guiso and Schivardi (2017).
Emergencies Funds	This is a dummy variable equal to 1 if the SBO does not set aside funds to deal with emergencies.	Weinstein (1980); Perloff and Fetzer (1986); Hoorens and Buunk (1993); Dawson (2017); Guiso and Schivardi (2017).
RCG	This variable measures the 'Rose-Colored Glasses' effect. SBOs were asked if they expect more good things than bad things in life. The variable is normalized to the standard unit interval, with higher values indicating greater optimism.	Scheier and Carver (1985); Lovallo and Kahneman (2003); Dawson and Henley (2012)

Table 3. Descriptive statistics

Variable	Mean	SD	Minimum	Maximum
Structural				
Omega (ω)	0.479	0.340	0	1
Domestic	0.944		0	1
Regions: Piedmont and Aosta Valley	0.082			
Lombardy	0.164			
Trentino – South Tyrol	0.001			
Veneto	0.074			
Friuli – Venezia Giulia	0.056			
Liguria	0.043			
Emilia – Romagna	0.164			
Tuscany	0.096			
Umbria	0.030			
Marche	0.032			
Lazio	0.043			
Abruzzo	0.007			
Molise	0.011			
Campania	0.077			
Apulia	0.058			
Basilicata	0.001			
Calabria	0.007			
Sicily	0.030			
Sardinia	0.025			
Industries: Mining	0.027			
Manufacturing	0.306			
Energy, water, telecommunications	0.009			
Building	0.089			
Trade, hotels, and restaurants	0.255			
Transportation	0.044			
Other services	0.270			
Risk attitude	0.431	0.232	0	1
Measurement				
Dedication (log)	2.127	0.354	0	3.178
Height (log)	5.149	0.048	4.997	5.298
Male	0.666		0	1
Perseverance	0.789	0.165	0	1
BTA	0.590	0.207	0	1
Accidents (higher values, lower probability)	0.898	0.199	0	1
Damages (higher values, lower probability)	0.903	0.198	0	1
Emergencies Funds (1 indicates no emergencies funds)	0.725		0	1
RCG	0.725	0.177	0	1

Source: our elaboration on data provided by Guiso and Schivardi (2017). The number of observations is 1,613. Omega (ω) is the fraction of SBO's wealth invested in her firm; Domestic is a dummy variable indicating when the SBO's company has no branches abroad; Risk attitude measures the SBO's attitude toward risk; Dedication measures the SBOs' dedication to working; Perseverance measures the SBO's degree of perseverance; BTA measures the SBO's degree to which she considers herself better than average; Accidents measures the SBO's perception of the probability of having accidents compared to the industry average; Damages measures the SBO's perception of the probability of causing damages compared to the industry average; Emergencies Funds is a dummy variable indicating SBOs who do not save funds to deal with emergencies; RCG measures the so-called 'Rose-Colored Glasses' effect obtained by asking SBOs if they expect more good things than bad things in life. For a more detailed description of these variables please refer to Table 2.

Table 4. Correlations

	Omega (ω)	Domestic	Risk attitude	Dedication (log)	Height (log)	Male	Perseverance	BTA	Accidents	Damages	Emergencies Funds	RCG
Omega (ω)	1											
Domestic	0.14***	1										
Risk attitude	-0.05*	-0.03	1									
Dedication (log)	0.06**	-0.05*	0.02	1								
Height (log)	0.03	-0.03	0.07***	0.09***	1							
Male	0.08***	-0.03	0.06**	0.12***	0.64***	1						
Perseverance	0.05*	-0.03	0.07***	0.24***	0.08***	0.07***	1					
BTA	0.00	-0.06**	0.06**	0.07***	0.14***	0.09***	0.17***	1				
Accidents	-0.05*	0.01	-0.07***	0.03	-0.02	-0.02	0.08***	-0.03	1			
Damages	-0.01	0.01	-0.09***	0.03	0.01	0.00	0.07***	0.03	0.56***	1		
Emergenc. Funds	-0.01	0.01	-0.07***	0.00	-0.06**	-0.03	-0.05*	0.01	0.10***	0.10***	1	
RCG	0.02	-0.03	0.06**	0.10***	-0.00	-0.02	0.25***	0.12***	0.03	0.06**	-0.03	1

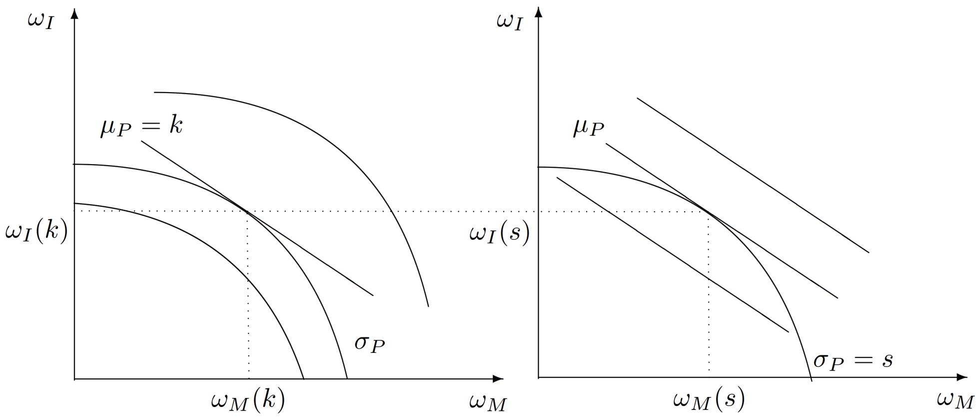
Significant correlation coefficients are indicated by the usual significance levels: ***1% **5% *10%. The number of observations is 1,613.

Table 5. Robustness checks

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
				Omega (ω) equation				
Overconfidence	0.078***	0.045	0.078***	0.276	0.084**	0.080***	0.078**	0.079**
	(0.030)	(0.104)	(0.030)	(0.267)	(0.041)	(0.030)	(0.031)	(0.031)
Over-optimism	-0.043	-0.639	-0.043	-0.541	-0.054	-0.045	-0.042	-0.045
	(0.033)	(0.951)	(0.033)	(0.876)	(0.033)	(0.034)	(0.033)	(0.034)
Domestic	0.135***	0.157***	0.135***	0.160***	0.138***	0.137***	0.136***	0.140***
	(0.025)	(0.045)	(0.025)	(0.042)	(0.025)	(0.025)	(0.025)	(0.024)
Risk attitude	-0.045*	-0.089	-0.045*	-0.099	-0.048*	-0.047*	-0.049**	-0.050**
	(0.025)	(0.080)	(0.025)	(0.076)	(0.025)	(0.025)	(0.025)	(0.025)
Height					-0.029			
					(0.032)			
Male					0.094***			
					(0.031)			
Region fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	No	Yes	No
				Overconfidence equation				
Omega (ω)		0.037		-0.202				
		(0.105)		(0.437)				
Over-optimism			-0.009	-0.025				
			(0.039)	(0.557)				
				Over-optimism equation				
Omega (ω)		0.629		0.511				
		(0.938)		(0.977)				
Overconfidence			-0.004**	-0.114				
			(0.002)	(0.513)				

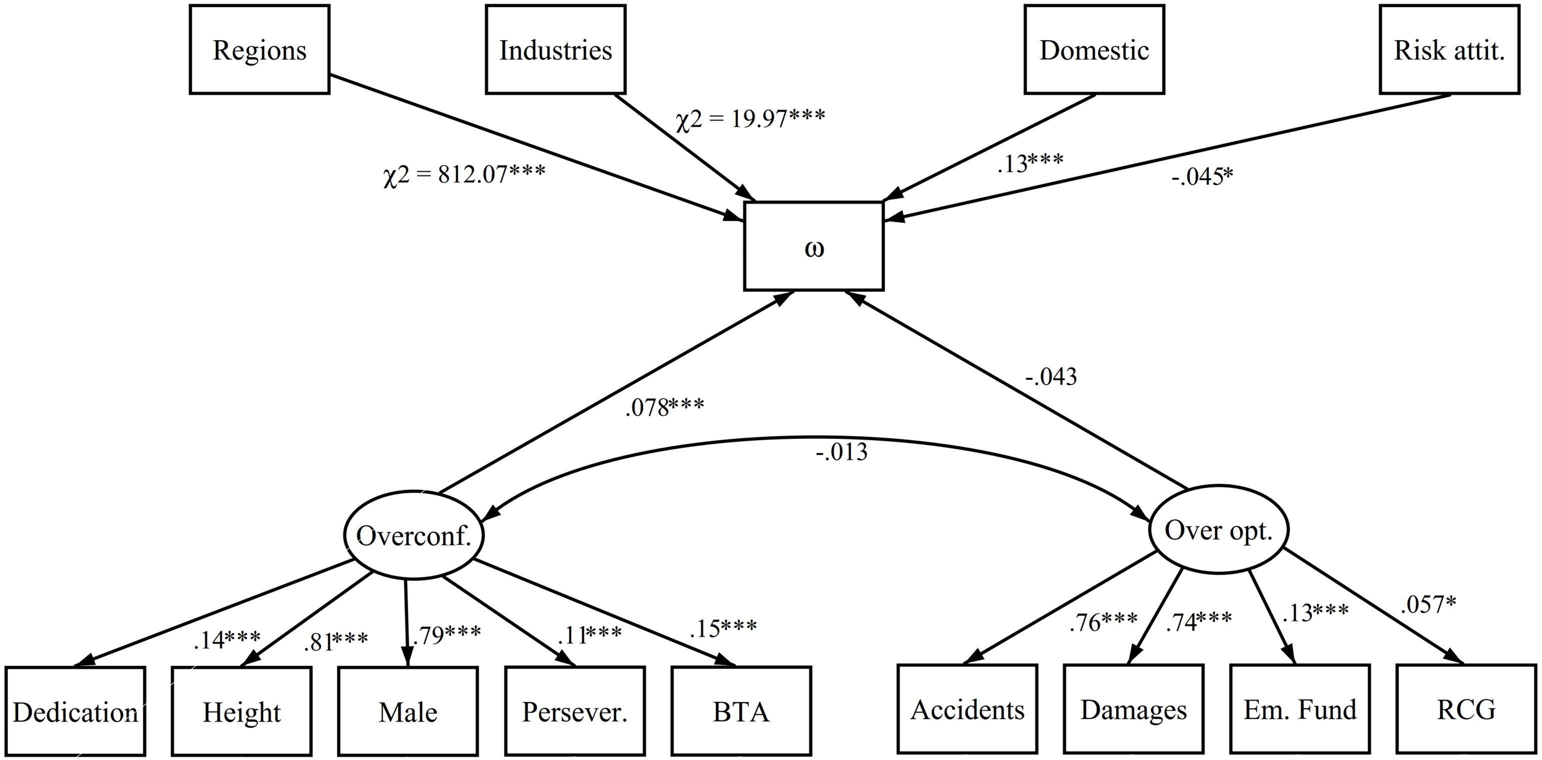
Significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The number of observations 1,613. All models include a constant. Standardized coefficients. Robust SEs in parenthesis. Overconfidence is the latent variable measured by Dedication, Height, Male, Perseverance, and BTA; Over-optimism is the latent variable measured by Accidents, Damages, Emergencies Funds, and RCG; Domestic is a dummy variable indicating when the SBO's company has no branches abroad; Risk attitude measures the SBO's attitude toward risk; omega (ω) is the fraction of SBOs' wealth invested in their companies.

Figure 1. Duality in portfolio optimization



k is the given value of portfolio expected excess return μ_P; s is the given value of portfolio standard deviation σ_P; ω_I the portfolio weight in the private company; ω_M is the portfolio weight in the market portfolio.

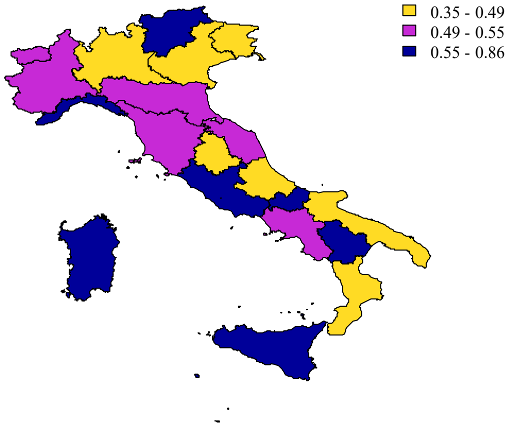
Figure 2. Estimated model



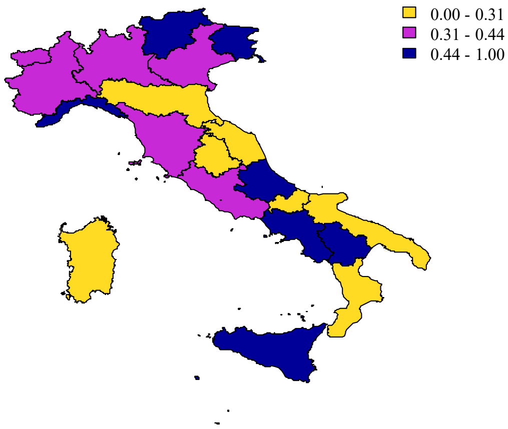
Significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The number of observations is 1,613. All models include a constant. Standardized coefficients. Omega (ω) is the fraction of SBOs' wealth invested in their companies; Domestic is a dummy variable indicating whether the SBO's company has branches abroad; Risk attitude measures the SBO's attitude toward risk; Dedication measures the SBOs' dedication to working; Perseverance measures the SBO's degree of perseverance; BTA measures the SBO's degree to which he considers himself/herself better than average; Accidents measures the SBO's perception of the probability of having accidents compared to the industry average; Damages measures the SBO's perception of the probability of causing damages compared to the industry average; Emergencies Funds is a dummy variable indicating SBOs who do not save funds to deal with emergencies; RCG measures the so-called 'Rose-Colored Glasses' effect obtained by asking SBOs if they expect more good things than bad things in life. Overconfidence and Over-optimism, enclosed in ovals, are latent variables.

Figure 3. Regional distribution of omega (ω), overconfidence, and over-optimism

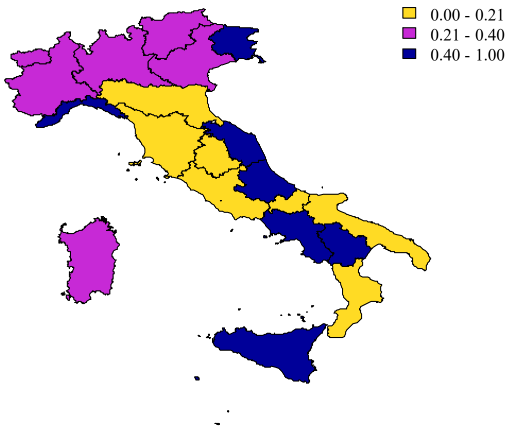
Weight in the private company



Overconfidence



Over optimism



The maps show regional averages. Darker colors indicate higher values. Overconfidence and Over-optimism are normalized to the standard unit interval.

Table A1. Implicit overconfidence and over-optimism levels – parameters from Kerins *et al.* (2004)

Panel A – Overconfidence effects on risk minimization

δ_C	0.0	0.2	0.4	0.6	0.8	$\cong 1.0$
$\widetilde{\omega}_I$	0.343	0.412	0.480	0.534	0.563	0.561

Panel B – Over-optimism effects on return maximization

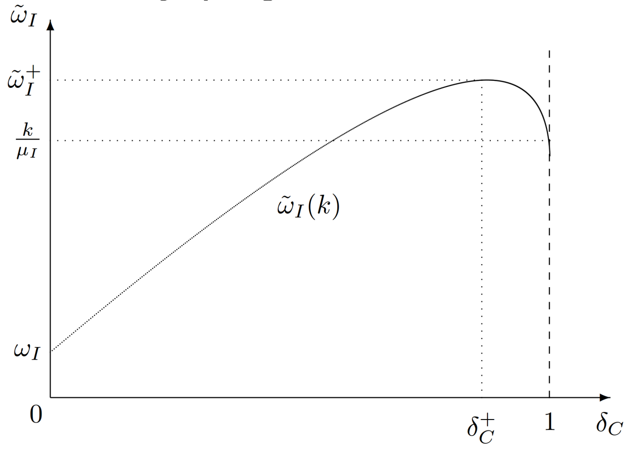
δ_O	0.0	0.2	0.4	0.6	0.8	$\cong 1.0$
$\widetilde{\omega}_I$	0.343	0.383	0.421	0.452	0.472	0.479

Parameters

k	s	μ_I	μ_M	σ_I	σ_M	ρ_{IM}
0.300	0.566	0.535	0.06	1.204	0.162	0.195

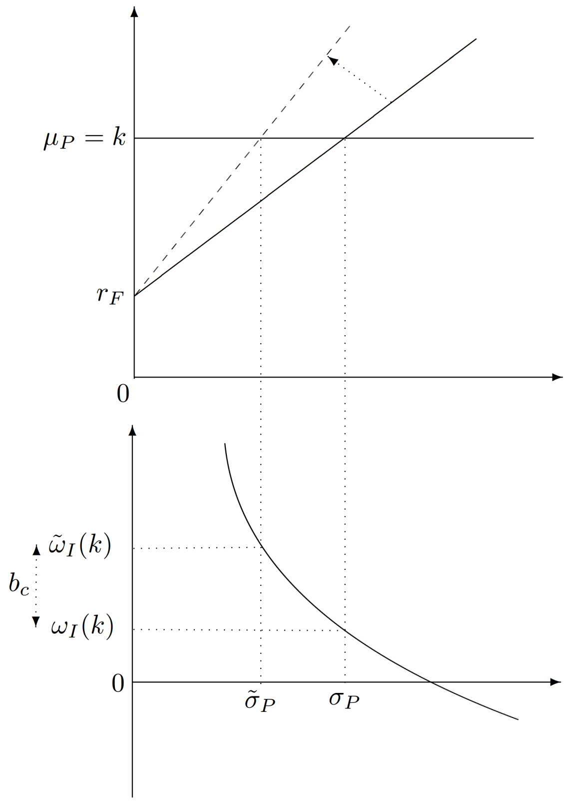
δ_C is the overconfidence parameter; δ_O is the over-optimism parameter; $\widetilde{\omega}_I$ is the biased portfolio weight in the private company; k is the given value of portfolio expected excess return; s is the given value of portfolio standard deviation; μ_I is the private company excess return over the risk-free rate; μ_M is the market portfolio excess return over the risk-free rate; σ_I is the private company standard deviation; σ_M is the market portfolio standard deviation; ρ_{IM} is the correlation between the private company returns and the market returns.

Figure A1. Private company weight in case of overconfidence and $\rho_{IM} > 0$



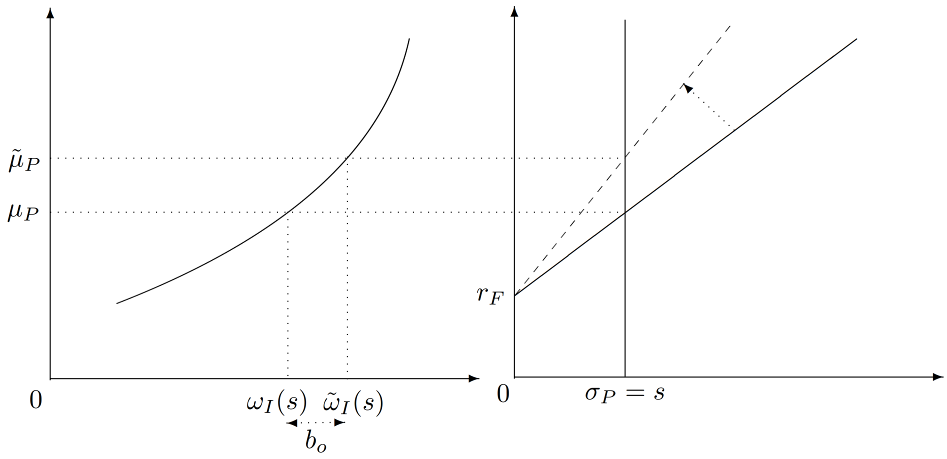
δ_C is the overconfidence parameter; $\widetilde{\omega}_I$ is the biased portfolio weight in the private company ω_I; k is the given value of portfolio expected excess return; μ_I is the private company excess return over the risk-free rate.

Figure A2. Frontier shift and overconfidence bias



k is the given value of portfolio expected excess return μ_P; r_F is the risk-free rate; $\tilde{\sigma}_P$ is the biased portfolio standard deviation σ_P; $\tilde{\omega}_I$ is the biased portfolio weight in the private company ω_I; b_c is the overconfidence bias.

Figure A3. Frontier shift and over-optimism bias.



s is the given value of portfolio standard deviation σ_P; r_F is the risk-free rate; $\tilde{\mu}_P$ is the biased portfolio excess return μ_P; $\widetilde{\omega}_I$ is the biased portfolio weight in the private company ω_I; b_o is the over-optimism bias.