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Founder Personality and Scaling Decisions in Entrepreneurial Firms

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Founder Personality and Scaling Decisions in Entrepreneurial Firms

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Abstract

Personality drives human decision-making. Research on corporate research and development (R&D), however, typically considers strategic decision-making to be independent of the decision-maker's personality traits. This study investigates the impact of CEO personality on scaling activities in young firms. In particular, we focus on R&D and investment decisions building on an entrepreneurial decision model that illustrates the different roles of major personality traits (ROCEAN: risk tolerance, openness to experience, conscientiousness, extraversion, neuroticism) in taking both R&D and investment decisions. Results based on detailed data from founders in 4,732 startups founded between 2011 and 2017 in Germany, show that scaling decisions in entrepreneurial firms are strongly imprinted by the CEO's personality. We find that higher risk tolerance and openness to experience result in a higher likelihood that the firm engages in R&D but only the former matters for levels of R&D expenditures. Comparing R&D decisions to tangible investments, we find that risk tolerance plays a more prominent role in the former but higher scores for openness also drive tangible investments. Founders with higher scores for agreeability and neuroticism are less likely to invest in growth in terms of R&D and tangible investments. More conscientious founders show lower R&D engagement but invest more in tangible assets. We discuss implications for entrepreneurship research and policy.

Keywords: Start-ups, Research & Development, Investment Decisions, Personality Traits, Risk tolerance

JEL-Classification: D91, G11, L26, O32, O33

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1 Introduction

Entrepreneurial companies contribute to radical innovation and the diffusion of new technologies as important drivers of economic development (Wennekers and Thurik, 1999; Van Praag and Versloot, 2007; Haltiwanger et al., 2013). However, the success of new firms substantially depends on the entrepreneurs that found them (Shane and Stuart, 2002; Dencker and Gruber, 2015) and the ways in which they think, decide, and act. The personality of the founder, therefore, likely plays an important role in shaping entrepreneurial behavior and decision-making (Costa and McCrae, 1997; Smith et al., 2018; Chapman and Hottenrott, 2022, 2024).

Differences in personality become apparent in career choices (Stewart and Roth, 2001; Brandstätter, 2011) and influence decisions within professional roles (Kerr et al., 2017). Personality has also been shown to affect people's entry into self-employment (Runst and Thomä, 2022a). Since most actions in young, entrepreneurial firms are initialized by the founder (Rauch and Frese, 2000), founders' personality likely plays a key role in all decisions that determine their firm's development including the search for and processing of information (Winter et al., 1998). For instance, important parts of entrepreneurial discretion, including planning, goal setting and strategy, are driven by preferences, expectations and sometimes subjective assessments of choice options. Founder personality likely shapes these factors and therefore explains the link between the personal attributes and entrepreneurial accomplishments of founders (Caliendo and Kritikos, 2008; Rauch et al., 2009). Founder personality traits have indeed been empirically linked to the success of start-ups (Zhao et al., 2010; Brandstätter, 2011; Jong et al., 2013; Rosenbusch et al., 2013). For instance, founders who are more open and proactive and ready to take risks, are more likely to search for, detect and exploit new opportunities that can drive their firm's growth (Covin and Slevin, 1991; Rauch and Frese, 2007). Founders who are more performance-oriented or competitive are also more inclined to seek external finance (Vaznyte and Andries, 2019; Chapman and Hottenrott, 2024) which may translate into better growth trajectories.

Based on these insights, this study investigates the impact of founder personality on early-stage investments and Research & Development (R&D) decisions. Investigating the role of founder personality for strategic decisions, such as investments in R&D, appears particularly crucial given the importance of such early-stage strategies for new venture growth and survival (Stam and Wennberg, 2009; Braymen et al., 2011). This idea is supported by Caggese (2012) who investigates the role of uncertainty for risky R&D investments and concludes that R&D engagement is strongly determined by risk tolerance. However, personality is multidimensional

consisting also of traits beyond risk preferences. If not only risk attitudes, but personality more broadly indeed drives R&D and investment decisions in young entrepreneurial firms, this may explain the previously identified performance link between certain personality traits and entrepreneurial success.

Identifying individual-level drivers and impediments of entrepreneurial success is important for understanding the role of young firms in knowledge-based economies. While previous research examined determinants of investment activity more generally (Cassar and Friedman, 2009), the role of personality for R&D and investment decisions in entrepreneurial firms remains less well understood. Looking at larger, more established firms, Barker and Mueller (2002) show how CEO characteristics relate to R&D spending and find that younger, R&D-experienced CEOs and those with higher financial stakes in the firm invest more. This implies that even in larger firms, R&D decisions are affected by the individual attributes of the decision-makers. More recently, Runst and Thomä (2022b) document that also in SMEs decision makers' personality plays a role in engaging in the DUI (doing-using-interacting) innovation mode rather than setting up formal R&D processes.

Adding to these insights, our analysis focuses on the link between founder personality and R&D and tangible investments as important components of young firms' innovation and scaling strategy. We derive testable propositions based on a model of entrepreneurial decision-making under uncertainty which explicitly incorporates personality in the assessment of investment options. We consider founder personality to consist of five basic dimensions (Big 5) (Costa and McCrae, 1997; George and Zhou, 2001; Zhao and Seibert, 2006; Rauch and Frese, 2007).[1] These personality traits reflect distinct dimensions of human personality: Openness to experience (O) captures how pronounced imaginative, curious, and accepting of novel and unorthodox ideas, perspectives and experiences an individual is, as opposed to preferring convention and familiarity. Conscientiousness (C) illustrates the manifestation of the properties of diligent, task-directed, achievement-oriented and rule-obedient, while extroversion (E) reflects the extent to which someone is assertive, active and impulsive. The fourth dimension – agreeableness (A) – reflects benevolence towards others as well as how conflict-eschewing and how anxious about negative consequences a person is. Finally, neuroticism (N) scores higher in individuals who display little self-confidence, are indecisive and cannot easily adapt to new circumstances. Besides these baseline personality traits, we consider entrepreneurial risk tolerance in line with the literature

[1] A recent study by Bainbridge et al. (2022) finds that between 71% and 83% of all commonly used psychological scales can be considered facets of the Big Five scale by showing high correlations to the Big Five.

on entrepreneurial decision making (Rauch and Frese, 2007; Caliendo et al., 2009; Caliendo et al., 2020) and recent evidence that the Big 5 traits do not fully capture risk tolerance (Piovesan and Willadsen, 2021).

The simple decision model illustrates that personality matters more when there is more room for subjective judgment, i.e. when residual uncertainty is higher. This suggests that founder personality matters more for R&D than for tangible investments. Since R&D decisions are typically characterized by a higher degree of uncertainty compared to investments in tangible assets (Czarnitzki and Hottenrott, 2011), the assessment of the expected returns depends more on the personality of the individual decision maker. Moreover, we differentiate between investment decisions at the extensive and intensive margins to illustrate the differential impact of personality traits on the decision to invest versus the scale of the investment.

We test the predictions from our theoretical considerations in an empirical analysis of entrepreneurs in 4,732 new firms founded between 2007 and 2017 in Germany. The results confirm that personality indeed predicts R&D decisions as well as investments in tangible assets. Even after controlling for other founder characteristics and different attributes of their ventures that may drive (or hinder) investment, we find that risk tolerance explains R&D activities at both extensive and intensive margins. Other traits matter more at the extensive margin. Openness is the main driver of engaging in R&D, but openness also matters for tangible investment, although to a lesser extent. Conscientiousness, on the other hand, negatively affects R&D engagement and the decision to invest, but shows a positive association with the amount invested in tangible assets. In fact, conscientiousness and extraversion both positively relate to larger amounts invested in tangible assets, but not in R&D. Higher levels of agreeableness and neuroticism make both engagement in R&D and investment in tangible investments less likely and relate to lower investments in firm growth.

These results have implications for entrepreneurs as well as for innovation research and policy. Since personality traits show a high degree of stability across time as well as context (Costa and McCrae, 1997; Roccas et al., 2002; Cobb-Clark and Schurer, 2011) and affect firm behavior, founder personality has a lasting impact on the performance of new firms. This study adds to our understanding of the large variation in start-up growth, survival, and innovation performance. With an analysis of start-ups, we contribute to research on high-growth strategies of newly founded businesses which allow a better understanding of their role as drivers of innovation and economic growth. Our results may also guide founders when deciding about team

composition such as to counterbalance an overly aligned decision-making or too high degrees of psychological similarity between founders. Founders who knowingly choose certain entrepreneurial personalities as co-founders could reinforce, off set or reverse behavioral dynamics. From an entrepreneurship policy perspective, the results imply that the success of policies designed to encourage R&D activities may depend on which founders they reach. Finally, our findings point out the importance of taking into account founder personality in future research which explores the nature of R&D (routine versus cutting-edge) and the types of innovation strategies that entrepreneurs pursue.

2 Personality and Entrepreneurial Investment Decisions

Investment decisions are among the most important decisions of entrepreneurs and managers. Especially R&D decisions are among the most fundamental strategic choices made by top managers (Scherer, 1984; Graves, 1988; Czarnitzki and Hottenrott, 2011; Wang, 2014; Becker et al., 2022). The decision makers' personality is likely important for investment decisions in small entrepreneurial firms in which the CEO or other members of the top management team are highly influential. This is especially true for decisions under uncertainty such as investment decisions in young firms with high situational and time pressure. Byrne et al. (2015) find that both neuroticism and agreeableness negatively affect decision making quality under both situational and time pressure. Recent research also suggests that risk tolerance and baseline personality traits are complementary measures of individual personality (Carson et al., 2020; Piovesan and Willadsen, 2021). This highlights the need to investigate decisions with different degrees of risk as well as to take into account both the Big 5 personality traits and risk tolerance. The following section aims to structure our expectations on the role of different personality traits in entrepreneurial investment decisions.

2.1 A two-stage model of Personality and Investment

In the following, we present a simple theoretical framework for investment decisions. We consider two different types of investment, that is, R&D investments and tangible investment options, as well as the fact that those decisions involve both the extensive (i.e., whether to invest at all) as well as the intensive margin (i.e., how much to invest).

An important factor in risky decisions, such as R&D, is the evaluation of the prospective returns which partly relies on subjective assessment of risk. Hirsh et al. (2008) report that higher emotional stability relates to lower discounting rates among individuals with high cognitive

ability. Lower discounting rates mean a higher present value of future returns, which encourages R&D activities both at the extensive as well as the intensive margin. Moreover, anxiety relates to higher temporal discount rates which suggests that is negatively associated with R&D at both the external and internal margins (Ostaszewski, 1996).

We assume a two-stage decision mechanism for taking up an investment opportunity in an entrepreneurial venture. R&D and tangible investments are considered as the two types of entrepreneurial investment options which differ in their properties. In reality, R&D and tangible investments are not mutually exclusive, most likely, even not independent of each other. For our purpose, however, we consider a unified framework for studying the marginal effects of certain personality traits and risk tolerance on both types of investment decisions. $\boldsymbol{B} = \{O, C, E, A, N\}$ is the vector of the Big 5 personality traits, the elements of which enter the decision-making in different ways.

First, we assume that the entrepreneur decides whether to make an investment (in R&D or tangible assets, denoted hereafter as T) at all (i.e., extensive margin). In the second stage, the entrepreneur decides the amount of investment (i.e., intensive margin) conditional on the decision at the first stage. We consider the first stage as an entry decision:

$$e_i = \mathbf{1}(\text{expected net utility from the entrepreneurial investment } i > 0)$$

i denotes the type of the investment, $i \in \{R\&D, T\}$; $e_i = 1$ indicates that the investment is taken up and $e_i = 0$ means that the investment is not taken up. The total utility of the entrepreneur from taking up the investment is realized upon the decision on the investment amount in the second stage. The total utility of the entrepreneur, in our model, is not synonymous to the material utility from the financial gains due to taking up the investment. Instead, the material utility constitutes a part of the total utility while the other part comprises non-material utility gained out of the simple act of taking up the investment. Therefore, we assume that the personality traits of the decision-maker influence both material and non-material utilities. Further, we argue that different personality traits become important at different stages of decision-making and in different ways through their impact on the entrepreneur's capabilities and attitudes.

First, openness to experience increases the utility of the entrepreneur in taking up the investment, that is, when $e_i = \mathbf{1}$. The underlying idea here is that the simple act of taking up a new investment satisfies the entrepreneur's curiosity and provides her with the non-material utility

through meeting the urge to experience new challenges. Extraversion implies high assertiveness, active engagement, and high networking skills of the entrepreneur which enhances the financial return from the investment. Similarly, conscientiousness, which manifests in achievement-oriented and rule-obedient diligence, benefits the financial returns from the investment. On the contrary, neuroticism, which is responsible for anxiety, indecisiveness, and impulsiveness, is likely to lower financial prospects.

The role of agreeableness is less clear. In line with the interpretation of high agreeableness as a low preference for conflicts and greater caution, highly agreeable individuals will have a higher threshold for the level of total utility that makes an investment justifiable. Based on this understanding, we may expect this trait to have an impact at the extensive margin.

We will discuss supporting evidence for these assumptions based on the existing literature as we proceed through the decision-making model in the following. We start with stage II, which deals with the investment amount, before discussing the take-up decision in stage I.

2.2 Stage II: Intensive margin

Suppose, y_i is the expected financial return from an investment and x_i indicates the units of money invested. We assume a standard exponentiated utility function for risky assets and augment a standard GARCH-M model with the personality traits. Thus, the utility derived from the expected financial return is $U(y_i) = -exp(-ry_i)$, where

$$y_i = \begin{cases} \alpha_i E + (\theta_\mathbf{i}\zeta')x_i + \upsilon_i(C,N) + \epsilon_i & \text{if} \quad x_i > 0 \\ 0 \qquad \text{if} \quad x_i = 0 \end{cases} \tag{2.1}$$

with r being the coefficient for the constant absolute risk aversion. A lower value of r indicates a higher risk tolerance. ζ is the vector of founder and firm characteristics (e.g. education, work experience, team size, sector, legal form) which determines the effectiveness of per unit of investment. Extraversion (E) is stylized as a profitability-enhancing parameter. The idea is that an entrepreneur with higher extraversion is able to extract a higher return from the same amount of financial investment. This is because extraversion is positively related to assertiveness which involves being sociable and communicative which helps building and maintaining social networks with investors, suppliers, and customers (Caliendo et al., 2016). More extrovert individuals may also search for novelty, challenge, and achievement (Roccas et al., 2002) which makes them pick

R&D projects with higher returns. The parameters α_i and θ_i are the respective coefficients for E and ζ. The stochastic part of the return has two components: ϵ_i, the random error on the unit return, is distributed with mean zero and variance $\sigma^2_{\epsilon i}$; on the other hand, $\upsilon_i(C, N)$ is the *perceived* volatility of the returns which is a function of conscientiousness (C) and neuroticism (N) and is distributed with mean zero and variance $\sigma^2_{\upsilon i}(C, N)$. The joint variance is therefore

$$\sigma^2_i(C, N) = \sigma^2_{\upsilon i}(C, N) + \sigma^2_{\epsilon i} + 2\rho_{\epsilon\upsilon}\sigma_{\upsilon i}(C, N)\sigma_{\epsilon i} \tag{2.2}$$

The return from one unit of money invested has the mean $\alpha_i E + \theta_{\mathbf{i}}\zeta'$ and variance σ^2_i. Given that the entrepreneur invests x_i units of money in i, we can say that the financial return y_i is distributed with mean $\sim \alpha_i E + (\theta_{\mathbf{i}}\zeta')x_i$ and variance $x^2_i\sigma^2_i$. The optimal x_i at the intensive margin is determined by maximizing the expected utility $\overline{U(y_i)} = \alpha_i E + (\theta_{\mathbf{i}}\zeta')x_i - \frac{rx^2_i\sigma^2_i}{2}$. Accordingly, the optimal investment is given by

$$x^*_i = \frac{\theta_{\mathbf{i}}\zeta'}{r\sigma^2_i(C, N)}. \tag{2.3}$$

The main distinctions we draw between R&D and tangible investments are with respect to the volatility of the returns, in particular, both the perceived and the true components. As delineated above, the perceived volatility is a function of C and N. We assume that $\partial\sigma^2_{\upsilon R\&D}/\partial C > 0$ but $\partial\sigma^2_{\upsilon T}/\partial C < 0$. Note that $\sigma^2_{\upsilon i}$ indicates the perceived volatility of the returns. This follows from the pattern that conscientious individuals tend to have a preference for certainty. Moreover, conscientious individuals have been shown to display impulse control (George and Zhou, 2001), inhibition (Roccas et al., 2002), as well as conformity and task-directed behavior (Bernardino and Santos, 2016). Low conscientiousness facilitates overcoming the cognitive barriers of need for control, deliberation and conformity (Nicholson et al., 2005). These properties are inversely related to the very nature of R&D projects. For tangible assets, on the other hand, the direction is reversed so that we expect a positive link between conscientiousness and perceived volatility of tangible investment returns. Consequently, the more conscientious an entrepreneur, the higher their perceived volatility $\sigma^2_{\upsilon R\&D}$, implying a lower $x_{R\&D}$. For tangible investments, the case is the other way round - the more conscientious an entrepreneur is, the lower the perceived volatility $\sigma^2_{\upsilon T}$, implying a higher x_T.

Higher neuroticism is likely to increase the perceived volatility for both types of investments.

Hence, $\partial\sigma^2_{vi}/\partial N > 0$ for both $i \in \{R\&D, T\}$. The more neurotic an entrepreneur, the higher their perceived volatility, resulting in a higher joint variance and therefore lower amount invested regardless of the type of investment. Accordingly, neuroticism is assumed to directly affect the expectations regarding the financial returns from the investment by affecting the perceived volatility of returns. High neuroticism is linked to more pronounced anxiety about potential negative consequences (Nicholson et al., 2005), while less neurotic individuals show higher self-confidence and resilience in stressful situations (Zhao and Seibert, 2006). Moreover, distraction theory suggests that lower emotional stability deteriorates information integration under high pressure (Markman et al., 2006) and individuals with higher levels of neuroticism experience stronger emotional distress when faced with uncertainty (Jong et al., 2013).

Proposition 1: *At the intensive margin,*

(i) the more conscientious an entrepreneur is, the higher the investment in tangible assets and the lower the investment in R&D.

(ii) the more neurotic an entrepreneur is, the lower is the amount of investment regardless of the type of investment.

(iii) the more risk tolerant the entrepreneur is, the higher the amount invested in R&D as well in tangible assets.

(iv) R&D investments require a higher risk tolerance compared to a tangible investment of the same amount.

Support: Considering that R&D expenditures are riskier in comparison to tangible investments, we can claim $\sigma^2_{\epsilon R\&D} > \sigma^2_{\epsilon T}$. It follows from equation 2.2 that $\sigma_{R\&D} > \sigma_T$ for similar levels of C and N. Furthermore, our arguments about the effect of C and N on the perceived volatility σ_{vi} imply that the optimal investment (equation 2.3) in R&D is lower and the optimal investment in tangible assets is higher the more conscientious an entrepreneur is. In contrast, the optimal investment amount for both types of investments is lower for a more neurotic entrepreneur.

Since the parameter r appears only in the denominator of the optimal investment, a higher risk tolerance indicates higher optimal investments. This is in line with research stressing the role of risk tolerance for engaging in uncertain investments (Sataloff et al., 2005; Caliendo et al., 2010; Hvide and Panos, 2014; Carson et al., 2020). Therefore, given comparability in terms of other characteristics (ζ), $\sigma_{R\&D} > \sigma_T$ for similar levels of C and N implies that a given amount of R&D

investment demands a higher risk tolerance (i.e., a lower r) in comparison to the same amount of investment in tangible assets.

2.3 Stage I: Extensive margin

At the first stage or the entry stage, the entrepreneur decides whether to take up the investment at all. Let us denote the expected total utility of the entrepreneur from taking up investment i as

$$U_i = e_i[\phi_i(O)^{1/r} + U(y_i)] \ .$$

The first term inside the square bracket in the expression for U_i formalizes the non-material utility of taking up an investment which is due to the openness trait. Individuals with higher openness tend to be interested widely and draw utility from unusual thought processes (McCrae and John, 1992). They are more likely to be independent thinkers, value intellectual challenges (Jong et al., 2013), show intellectual curiosity (Zhao and Seibert, 2006), and are amenable to variety and novelty (George and Zhou, 2001). R&D investments typically call for more curiosity and a taste for change than regular investments in tangible assets (George and Zhou, 2001; Jong et al., 2013). Therefore, we can assume $\phi_{R\&D}(O) > \phi_T(O)$. The second term inside the square bracket, $U(y_i)$, gives the expected utility from the financial return which depends on the decision at the internal margin.

Let us assume that there exists an outside option with a certain value M which is less competitive than either type of investment. The net utility from choosing to invest over choosing the outside option is $U_i(e_i = 1) - M$. We further assume that $\eta(A)$ is an increasing function of agreeableness which moderates the importance of this net utility (from choosing to invest over choosing to go with the outside option) in the entry decision. The more pronounced the agreeableness trait is, the more likely it is that the entrepreneur chooses the less competitive option. In other words, the entrepreneur needs a higher expected utility from the investment option to find it more attractive in comparison to the less competitive outside option. The rationale behind this assumption is that higher scores in agreeableness reduce competitive thinking (Roccas et al., 2002; Caliendo et al., 2014; Byrne et al., 2015) and may therefore relate to a lower willingness to invest in any type of competitiveness-enhancing activities - R&D spending or tangible assets. The entry decision can be rewritten as

$$e_i = \mathbf{1}(\phi_i(O)^{1/r} + \overline{U(y_i)} - M - \eta(A) > 0)$$
$$= \mathbf{1}(\phi_i(O)^{1/r} + \alpha_i E + (\theta_\mathbf{i}\zeta')x_i - \frac{r x_i^2 \sigma_i^2}{2} - M - \eta(A) > 0).$$

The above condition is adapted from the entry decision model of Hvide and Panos (2014), although we have a fixed value for M, unlike their stochastic outside option. The expression inside the parentheses indicates that the stronger the agreeableness trait, the less likely it is for the entry condition to be satisfied. Incorporating the optimal solution from the second stage, the above can be written as

$$e_i = \mathbf{1}\left(\phi_i(O)^{1/r} + \alpha_i E + \frac{(\theta_\mathbf{i}\zeta')^2}{2r\sigma_i^2(C,N)} > M + \eta(A)\right). \tag{2.4}$$

This leads us to the following proposition.

Proposition 2: *At the extensive margin,*

(i) An entrepreneur with a higher level of openness is more likely to undertake the investment regardless of the type of the investment.

(ii) An entrepreneur with a higher level of extraversion is more likely to undertake the investment regardless of the type of the investment.

(iii) An entrepreneur with a higher level of risk tolerance is more likely to undertake the investment regardless of the type of the investment.

(iv) An entrepreneur with a higher level of conscientiousness is more likely to take up a tangible investment but less likely to take up an R&D investment.

(v) An entrepreneur with a higher level of neuroticism is less likely to undertake any sort of investment regardless of the type of the investment.

(vi) An entrepreneur with a higher level of agreeableness is less likely to undertake any sort of investment regardless of the type of the investment.

Support: Looking at expression 2.4, we see that openness, extraversion, as well as risk tolerance raises the left hand side of the inequality within the parentheses, making it easier for the entry condition to be met. It follows from equation 2.3 and Proposition 1.(i) that the investment in tangible assets is higher and investment in R&D is lower the more conscientious the entrepreneur is. Accordingly, the last term in the left hand side of the inequality in equation 2.4 is higher for

tangible investment and lower for R&D investment, the more conscientious an entrepreneur is. Higher neuroticism, on the other hand, always means that the left hand side of the inequality is lower. A more neurotic entrepreneur is therefore less likely to take up any investment. The agreeableness trait appears on the right hand side of the inequality and a higher value of the same makes it more difficult for the investment threshold to be reached. Hence, an entrepreneur with higher agreeableness is less likely to undertake any sort of investment.

3 Data and Method of Analysis

3.1 Data

The data used for the empirical analysis is part of the IAB/ZEW start-up panel. The panel was established in 2008 by the Center for European Economic Research (ZEW), the KfW Bankengruppe, and Creditreform to collect representative data on entrepreneurial firms in Germany. The survey is conducted annually via computer-assisted telephone interviews (CATI) and covers detailed information on the firms' founders, and business activities.[2]

Our focus is on independent ventures, that is, we eliminate firms that are de-mergers or spin-offs, franchises or subsidiaries of other firms. We make use of the 2018 and 2019 waves of the survey that contain detailed questions on founders' risk tolerance and Big 5 personality traits. The reference years for the survey questions are 2017 and 2018, respectively. After excluding observations with missing information, the final sample comprises 5,252 firm-year observations corresponding to 4,732 unique ventures founded during the period from 2011 to 2017.

R&D activity, Investments and R&D Intensity

R&D activity is measured in terms of the annual amount spent on R&D (R&D expenditures). If the value is above zero, the firm's status is R&D-active and the indicator R&D (binary) takes on the value 1 (otherwise 0). As an additional indicator of R&D activity, we scale R&D spending – which typically consists largely of wages of R&D employees – with the total number of employees. This R&D intensity accounts for firm-size differences in R&D activity (Becker et al., 2022). We further measure annual investments in tangible assets and differentiate between firms' (binary) investment decisions from the investment amounts (expenditures). When looking at these indicators across eleven different sectors, we see that the share of R&D-active firms as well as the amount spent on R&D differ by sector with the highest share of R&D-active (as well

[2]The survey is based on a stratified random sample based on sectors and regions. See Fryges et al. (2009) for a more detailed description of the data set.

as the highest amounts of annual R&D investments) firms in manufacturing and the lowest R&D engagement in non-knowledge-intensive service sectors.[3]

Personality Traits

Founders' personality traits are measured based on an established and standardized 15-item scale testing the manifestation of the Big 5 traits. The five-factor approach is a well-known model of personality traits (McCrae and John, 1992) and synthesizes the baseline personality of an individual (Goldberg and Saucier, 1998; Hurtz and Donovan, 2000). The five traits are openness to experience, conscientiousness, extroversion, agreeableness, and neuroticism, and are commonly abbreviated as 'OCEAN' (McAdams, 1992; Lumpkin and Dess, 1996; Lumpkin et al., 2009; Covin and Wales, 2012). Since risk tolerance is an important dimension in the entrepreneurial context, we complement the baseline personality traits with a two-item risk tolerance metric (Lumpkin and Dess, 1996; Anderson et al., 2015; Covin and Wales, 2019; Wales et al., 2020) which results in a set of six traits that can be abbreviated as 'ROCEAN'. Entrepreneurial risk tolerance reflects how much risk taking is acceptable to the entrepreneur. In this context, it reflects the propensity to accept the risks inherent in an opportunity, not the preference to risk as in sensation-, stimulation- or thrill-seeking per se (Ostaszewski, 1996; Nicholson et al., 2005).

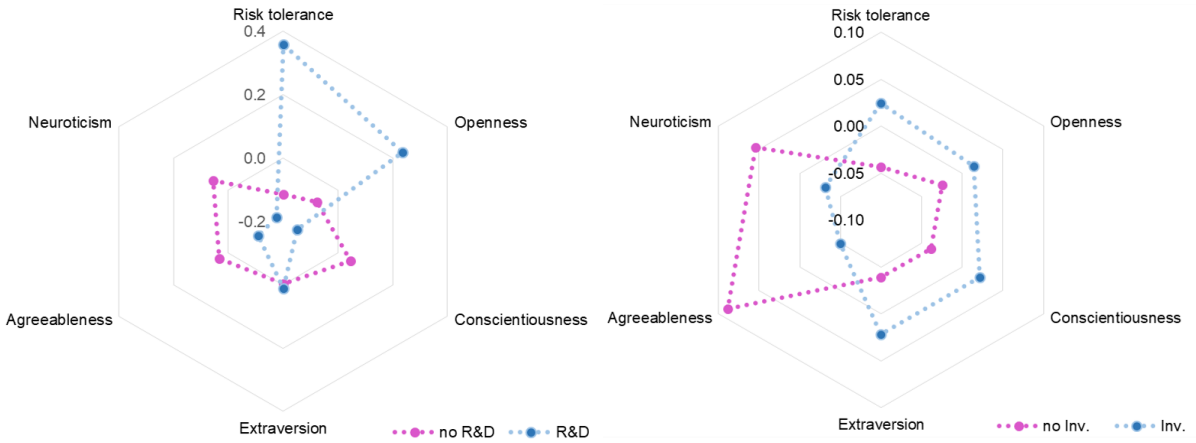
Table A4 shows the survey questions (items) in detail. We perform two separate principal component factor analyses: One on the two items measuring risk tolerance and one on the 15 items for the baseline personality traits. Table A5 shows the results of the first factor analysis and confirms that both items map into the latent factor 'risk tolerance'. Table A6 visualizes that each of the 15 items on personality traits correlates – as expected – strongly with one of the five underlying factors. We obtain the predicted factor scores (PFS) for each of the six traits from the factor analysis and use them as main explanatory variables in the following.

Figure 1(a) illustrates how the personality profiles differ between R&D-active and -inactive firms. In particular, risk tolerance and openness are substantially more prominent in founders who decide to engage in R&D compared to those who do not conduct any R&D in their firm. Besides that, conscientiousness, agreeableness and neuroticism are traits that are less pronounced in R&D-inactive founders. Only the degree of extraversion is about the same level in both groups.

[3] Appendix Table A1 shows the number of firms per year and the annual pattern of investment-related variables. Table A2 displays the distribution of firms across sectors and Table A3 shows the geographical coverage across German federal states.

When comparing personality profiles of investing to non-investing founders in Figure 1(b), we see also intriguing divergences. Here, the differences between groups in terms of risk tolerance and openness are less pronounced. Yet, we also see that agreeableness and neuroticism manifest to a greater extent in the non-investing group, while higher levels of risk tolerance, openness, conscientiousness, and extraversion substantiate in the group with investment activity.

Figure 1: Personality Profiles by Investment Type



(a) R&D decision

(b) Tangible investment decision

Control variables

In the econometric analyses, we control for commonly understood drivers of corporate R&D and investment decisions which can be categorized into founder and firm characteristics. At the founder level, 'Industry experience' may be a relevant factor for assessing the returns to R&D and investments more generally. Whether the entrepreneur is a re-starter, i.e. has founded a firm before the current one (Serial entrepreneur), reflects entrepreneurial experience beyond the specific industry. Furthermore, characteristics of the decision maker as a person include the entrepreneur's age (Age), gender (Female), and scientific biography with an indicator variable for individuals who have a university degree (Academic).

At the firm level, we control for the start-up's maturity with an indicator for firm age (Cohort), the value of its physical capital (Tangible assets), and firm size (Employees). The firm's legal form (Limited company) is of interest in the context of risk-taking behavior, since limited liability may allow for a higher risk readiness than a personal liability. Importantly, we also account for the founders' main motive for becoming an entrepreneur. We distinguish between founders who were opportunity-driven (Opportunity driven) and those who founded out of necessity, for instance, to escape unemployment. We consider a founder to be opportunity-driven if she/he states to

have pursued a specific business idea, saw an opportunity to increase her/his income, or pursued the opportunity to work more independently. Since team dynamics can impact decision-making, we also control for whether other founders were involved in the process (Team). Finally, the industry of business activity (Sector) and the firm's location within Germany (Federal state)[4], as well as a survey wave dummy (capturing changes in business prospects over time) are included in all models. We added 1€ where zero was observed and log-transform R&D and investment amounts, the stock of tangible assets as well as our measure for firm size to reduce distributional skewness.

3.2 Descriptive Statistics

Table 1 summarizes the main variables used in the estimations. The dependent variables describe whether founders decided to invest in R&D or in (non-R&D-related) tangible assets (binary indicators): Whereas more than half of entrepreneurs opted for general investments with a mean of 64%, it is only roughly a quarter (24%) who decided to invest in R&D. Conforming with this difference, the average value of €33,451 investments is higher than average R&D expenditures with €22,806. Also, the maximum values diverge strikingly: The largest amount for R&D is €5 million, while investments at most amount to double as much with €10 million. The average annual amount of R&D expenditures spent per employee is €5,200.

Concerning the characteristics at the founder level, the average founder has 17 years of industry experience and is 45 years old. About half of the entrepreneurs have completed a university (or college) degree (49.3%), 41% have founded a company before, and 17% of founders are women (or in the case of teams comprising at least one woman). At the firm level, the average firm is around 3.5 years old, employs around four employees (measured in full-time equivalents), and owns tangible assets worth approximately €11,000. On average, half of the firms are legally registered as limited companies and the vast majority was founded out of opportunity motives (84.8%) and by a solo founder (79%). Most of the founding activity takes place in Western Germany as only 21% of the firms are located in Eastern Germany.[5]

3.3 Method

Based on the previous theoretical considerations, we hypothesize that risk tolerance and personality traits have heterogeneous effects on R&D spending and tangible investment decisions.

[4]Previous research documents strong and persistent patterns of entrepreneurial personality within Germany (Fritsch et al., 2019) as well as differences in Big 5 traits across German states (Fritsch et al., 2018). Controlling for the federal state (*Bundesland*) fixed effects seems therefore crucial.

[5]Cross-correlations between the variables are presented in Tables A7-A9.

Table 1: Descriptive statistics of main variables

	Mean	Sd	Min	Max
Dependent variables				
R&D (binary)	0.241	0.428	0	1
R&D (expenditures)[1]	22,806	123,812	0	5,000,000
Tangible investments (binary)	0.640	0.480	0	1
Tangible investments (volume)[1]	33,451	266,113	0	10,000,000
R&D per employee[2]	5,200	29,043	0	1,200,000
Entrepreneurial and personality traits (ROCEAN)				
Risk tolerance	0.000	1	-1.539	1.862
Openness	0.000	1	-4.413	2.207
Conscientiousness	0.000	1	-6.016	1.696
Extraversion	0.000	1	-4.351	1.936
Agreeableness	0.000	1	-4.612	2.147
Neuroticism	0.000	1	-2.408	3.548
Founder characteristics				
Female	0.167	0.373	0	1
Founder age	45.158	11.237	18	99
University degree	0.493	0.500	0	1
Industry experience	17.266	10.552	1	58
Serial entrepreneur	0.409	0.492	0	1
Firm characteristics				
Employees (full time equivalents)	4.091	6.894	0	177.5
Tangible assets[1]	10,953	46,086	0	1,700,000
Limited company	0.536	0.499	0	1
Opportunity driven	0.848	0.359	0	1
Team founder	0.210	0.408	0	1
Cohort	3.431	1.755	1	7
East Germany	0.135	0.342	0	1
Observations (*Unique firms*)		5,252 (*4,732*)		

[1] Measured in €
[2] Some observations were omitted when calculating this ratio since the denominator was zero.

Specifically, the effects differ not only between these two investment types but also between the decision to invest (extensive margin), and the decision on the investment volume conditional on the decision to invest (intensive margin). In accordance with the literature, we assume that risk tolerance and personality traits remain constant over time (Costa and McCrae, 1997; Cobb-Clark and Schurer, 2011; Roccas et al., 2002), and that they are exogenous to R&D and investment decisions, i.e. there is no reverse causality or endogeneity. We model the founder's R&D and investment decisions as a function of personality as well as factors determining the need and opportunities for R&D and investment, such as founder and firm characteristics. We abstract from other firms' R&D decisions, presuming that the competitive environment is captured by the sector and region controls, the maturity should be captured by the cohort control, and the short-term business cycle by the survey wave dummy.

In the empirical analysis, we model the decision to invest and the decision on the amount

to be spent jointly in two-stage selection models for both R&D and tangible investments. In particular, we estimate Heckman selection models that account for the fact that the outcome variables (R&D and tangible investments) are censored at zero, i.e. that investment amounts are either zero or positive and not observed for firms that do not invest. We model this sample selection explicitly with the selection equation representing the decision to engage in R&D on the first stage (extensive margin), and the second stage equation reproduces how much to invest conditional on the decision to invest (intensive margin).

The model can be written such that there is a selection equation

$$\text{R\&D} = \boldsymbol{Z}^T\gamma + \epsilon_1 \tag{3.1}$$

and an outcome equation with

$$\ln(\text{R\&D expenditures}) = \boldsymbol{X}^T\beta + \epsilon_2 \tag{3.2}$$

with $\epsilon_1 \sim N(0;\sigma)$ as well as $\epsilon_2 \sim N(0;1)$ and $corr(\epsilon_1, \epsilon_1) = \rho$. If $\rho \neq 0$, standard regression techniques may yield biased results and the Heckman selection model should provide consistent, asymptotically efficient estimates for all the parameters in such models as explained in the following. The specification for tangible investment decisions is defined accordingly.

The identification of the second stage, however, requires valid exclusion restrictions (ER). These are typically defined by the researcher based on theoretical reasoning. Often it remains unclear whether the selected excluded variables were indeed the theoretically and technically best-suited ones. Following the approach developed by (Farbmacher, 2021)[6], we employ a novel approach which proposes use LASSO techniques to (machine) learn about the best available ER. The advantage of employing machine learning in selection models is that we do not rely on researchers' choice and reasoning alone regarding the choice of ER. Instead, the identification of technically valid the ER is data-driven analysis. The selection of variables is based on a Least Absolute Shrinkage and Selection Operator (LASSO) approach to select which covariates should be included in the outcome model. LASSO prevents overfitting by the reduction of potential regressors to the ones reliably explaining variation in the outcome[7]. For this purpose, LASSO imposes a penalty term which is composed of the sum of the absolute (A) coefficients and weighs this

[6]The code for the estimation can be obtained from: https://github.com/farbmacher/heckman_lasso
[7]The so-called sparsity assumption reduces overcomplexity in high-dimensional models.

penalty according to the tuning parameter λ that determines the extent of shrinkage (S)[8]. When producing coefficient estimates, the penalty constrains coefficient values towards zero, such that less relevant variables amount to close or equal to zero and are discarded. Model selection (S) is thus performed in conjunction with coefficient estimation. The LASSO approach thus provides a data-driven approach to selecting ER.

When applying this approach, we can shield some variables from penalization, i.e. variables that should be included in the final post-LASSO-Heckman regression for conceptual reasons. This is plausible for variables that we would want to be included in both stages such as industry dummy variables or cohort indicators. We therefore first exclude the ROCEAN traits and the sector, federal state, and survey wave fixed effects from serving as exclusion restrictions and present the results in Table 2.[9]

We present the estimated coefficients from the two Heckman models in the same table with the results for the intensive margin in the left column, the results for the extensive margin in the mid column, and the average marginal effects in the right column. The average marginal effects refer to the first-stage estimation. The λ values are statistically significant suggesting that the two stages are indeed not independent from each other.

The results show that for R&D decisions, the Big 5 traits matter more at the extensive than the intensive margin. While higher openness and extroversion increase the odds that a founder takes up R&D projects (in line with proposition 2), only her risk tolerance explains higher amounts of R&D. Higher scores for conscientiousness, agreeableness and neuroticism negatively predict R&D at the extensive margin, but not at the intensive margin. The picture looks different for tangible investments. Here, risk tolerance does not impact the decision to invest (while openness does), but the amount (while openness does not). Notably, higher degrees of conscientiousness and extraversion explain higher investment amounts in the case of tangible investments (in line with proposition 1), but not the decision to invest (in line with proposition 2). For tangible investments, agreeableness and neuroticism matter both at the extensive and the intensive margin indicating that founders with higher scores in these two traits are less likely to invest and also invest smaller amounts.

[8]When λ=0, linear LASSO equals the OLS estimation. The cost of each nonzero β grows in union with the penalty term that covaries with λ. An increasing λ shrinks the magnitude of the estimated coefficients.

[9]We relax this in robustness tests (see Tables A10 and A11 for the results with more flexible exclusion restrictions). Moreover, we test the robustness of the results to the use of researcher-selected exclusion restrictions (see Table A12 for these results).

Table 2: Estimation results for R&D and investment decisions (LASSO-Heckman)

	Models: R&D decision			**Models: Tangible investment decision**		
	Intensive margin	Extensive margin	Average marginal effects	Intensive margin	Extensive margin	Average marginal effects
Risk tolerance	0.291***	0.138***	0.032***	0.105***	0.013	0.004
	(0.065)	(0.023)	(0.005)	(0.023)	(0.020)	(0.007)
Openness	0.028	0.255***	0.059***	-0.010	0.043**	0.015**
	(0.102)	(0.025)	(0.006)	(0.025)	(0.020)	(0.007)
Conscientiousness	0.001	-0.054**	-0.012**	0.075***	0.032	0.011
	(0.046)	(0.024)	(0.006)	(0.024)	(0.020)	(0.007)
Extraversion	0.022	-0.025	-0.006	0.062***	-0.005	-0.002
	(0.043)	(0.024)	(0.006)	(0.024)	(0.020)	(0.007)
Agreeableness	-0.044	-0.064***	-0.015***	-0.087***	-0.083***	-0.029***
	(0.045)	(0.023)	(0.005)	(0.028)	(0.020)	(0.007)
Neuroticism	-0.059	-0.078***	-0.018***	-0.063**	-0.050***	-0.017***
	(0.048)	(0.023)	(0.005)	(0.025)	(0.019)	(0.007)
Female	-0.332**	-0.192***	-0.044***	-0.236***	-0.192***	-0.067***
	(0.130)	(0.065)	(0.015)	(0.075)	(0.051)	(0.018)
Founder age	0.018***	-0.003	-0.001	-0.004	-0.010***	-0.003***
	(0.004)	(0.003)	(0.001)	(0.003)	(0.002)	(0.001)
University degree	0.308*	0.393***	0.091***		0.105**	0.037**
	(0.175)	(0.051)	(0.012)		(0.043)	(0.015)
ln(employees)	0.872***	0.176***	0.041***	1.013***	0.288***	0.101***
	(0.082)	(0.035)	(0.008)	(0.064)	(0.031)	(0.011)
Limited company	1.125***	0.453***	0.104***	0.143**	-0.143***	-0.050***
	(0.212)	(0.054)	(0.012)	(0.060)	(0.045)	(0.015)
Opportunity driven	0.282**	0.101	0.023		-0.027	-0.010
	(0.128)	(0.066)	(0.015)		(0.052)	(0.018)
Industry experience		-0.001	-0.000	0.013***	0.007***	0.002***
		(0.003)	(0.001)	(0.003)	(0.002)	(0.001)
Serial entrepreneur		0.080*	0.018*		-0.126***	-0.044***
		(0.048)	(0.011)		(0.041)	(0.014)
ln(tangible assets)		0.009*	0.002*		0.015***	0.005***
		(0.005)	(0.001)		(0.004)	(0.001)
Team founder		0.089	0.020	-0.086	-0.028	-0.010
		(0.061)	(0.014)	(0.066)	(0.054)	(0.019)
Cohort		0.003	0.001	-0.125***	-0.139***	-0.049***
		(0.014)	(0.003)	(0.031)	(0.011)	(0.004)
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes
Federal state FE	Yes	Yes	Yes	Yes	Yes	Yes
Survey wave FE	Yes	Yes	Yes	Yes	Yes	Yes
λ	0.474***			0.536***		
Observations	5,252	5,252	5,252	5,252	5,252	5,252

Standard errors in parentheses (clustered at firm level)
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.010$

These findings also resonate with the predictions from our theoretical considerations. These results illustrate the importance of differentiating between the extensive and intensive margins as well as between R&D decisions and other investments. The finding that higher degrees of conscientiousness are associated with a lower likelihood to engage in R&D (while being positively associated with the amount of tangible investments) is also in line with our propositions. Conscientiousness involves being someone who enjoys conforming to a protocol and accomplishing tasks. Conscientious people work diligently and strive for goals, hence dislike a lack of rules and uncertainty in task completion. The nature of R&D activities is inherently risky and yields uncertain outcomes.

The results for other founder and firm variables are plausible. Being opportunity-driven is associated with higher amounts spent on R&D, incorporating as limited liability company is a strong predictor of scaling in terms of both R&D and investments. Founders' industry experience is positively related to higher tangible investment but not to higher amounts of R&D and firms that are already larger, are able to scale more.

The different drivers of R&D versus investment decisions are also reflected in the fact that the LASSO-selected ER differ between the R&D and investment models. For both the R&D and the investment equation, the exclusion restrictions appear plausible. While in the case of the former, we exclude experience (industry experience and serial entrepreneurship) and the stock of tangible assets, the team dummy and the age of the company (cohort), for tangible investments, it is university education and opportunity entrepreneurship. The serial entrepreneurship indicator and the stock of tangible assets were selected in both cases.

3.4 Additional checks

When we allow the ROCEAN traits to be excluded (see Table A11), we find indeed some of the traits can serve as ER. In the R&D model, this is the case for all traits except openness and risk tolerance. For investments, it is only openness that is excluded. Still, the main conclusions, as discussed above, hold in these specifications.

Before estimating the LASSO models and seeing the results, we selected some variables as ER based on previous research and logic as well as a simple test of relevance in the first stage and conditional insignificance in the second stage. We then compare the results with these researcher-selected ER to the ones discussed above. We chose the information on an academic degree, since founders with a higher education background may be more inclined to engage in

R&D or pursue a more scientific approach to decision-making that also affects the propensity to invest more generally (Camuffo et al., 2020). As a second ER, we employed the value of the stock tangible assets (logged). Tangible assets may determine production capacity and hence the need to invest as well, since they affect the expected returns to R&D and often represent complementary assets (Rothaermel and Hill, 2005; Ceccagnoli et al., 2010). As a third ER, we add the firm's development stage, measured in years since founding or simply the founding cohort.

Table A12 shows the results from these models. While the conclusions with regard to the traits remain as before, there are also some differences. Openness is now a negative predictor of the R&D amount which is not very intuitive and speaks against our theoretical considerations. For investments, agreeableness and neuroticism are no longer (negative) predictors of the investment amount. These differences illustrate possible limitations of the researcher-based approach for selecting exclusion restrictions. First, we picked fewer ER than the data would have suggested. Second, while there is some overlap between the LASSO ER and ours, we would have excluded not necessarily the best ones from a statistical point of view. For example, the 'academic' status from the second stage in both models due to weak statistical significance while based on LASSO we should have done so only in the investment model.

4 Conclusion and Discussion

This study highlights the role of founder personality in the decision making in entrepreneurial firms. The analysis focused on investments in intangible assets through R&D activities and compared these to investments in tangible assets. The presented analyses build on and add to prior work on firm performance (Rauch et al., 2009; Jong et al., 2013; Dencker and Gruber, 2015) and CEO personality (Lumpkin and Dess, 1996; Frese, 2009; Zhao et al., 2010). The study also adds to recent research that linked decision-maker personality to innovation strategy in non-R&D settings, i.e. in SMEs that conduct none to little R&D (Runst and Thomä, 2022b).

Making use of detailed data from a large sample of founders, we provide evidence that founders' ROCEAN traits determine R&D decisions as well as other investment choices. Interestingly, there are common patterns, but also differences in the role of the distinct attributes in these strategic decisions. The findings from the empirical analysis confirm most of the predictions from our simple model of entrepreneurial investment decision-making. First, we hypothesized that risk tolerance matters for both investment types, but should matter more for R&D expenditures than

for tangible investments at the extensive margin. The results indeed demonstrate that founders who are more risk-loving are more likely to invest in R&D than other founders. However, only for R&D, the amount spent on R&D rises with the level of risk tolerance of the decision maker.

Second, we proposed that a higher degree of openness to experience should affect both investment types. Yet, at the extensive margin, it should be more relevant for R&D than for tangible investments. This is indeed confirmed in our data. It was, however, somewhat surprising that greater openness does not result in higher amounts spent on R&D. This suggests that founders may value engaging in new projects that affect the single founder's openness to (new) R&D projects, adding to the variety of the R&D portfolio, but does not result in higher investment volumes. In this regard, risk tolerance and openness are, in fact, quite different personality dimensions that do not necessarily result in similar outcomes.

Third, we argued that conscientiousness might impact both types of investment, but in opposite directions. As conscientious founders may value unpredictable outcomes less than those who score lower on that trait, they may be less keen to engage in R&D projects which are inherently uncertain and may not only be characterized by procedural uncertainties but also involve substantial outcome and market uncertainty. For more predictable, and in that sense attainable, investment, on the other hand, we would expect that higher conscientiousness results in higher investment as this could be expected to reduce the failure risk of the firm overall. We find support for this theoretical reasoning, as more conscientious founders are less likely to engage in R&D, but to invest greater amounts in tangible assets.

The expectations regarding the role of extroversion as a trait based on previous research were less clear, but given the potential importance of communication and networking skills also for entrepreneurial expansion strategies, we hypothesized that there could be a positive link between extraversion and both types of investment. However, the results only confirm that extroversion is positively associated with the amount invested in tangibles.

Fifth and sixth, we proposed that higher degrees of agreeableness and neuroticism should be related to lower investments overall. This affects both the decision to invest and the amount spent. The expected negative association between agreeableness as well as neuroticism with entrepreneurial growth strategies are indeed confirmed by our results. The insignificance of neuroticism at the intensive margin in the R&D model is likely due to the fact that starting new projects bears high uncertainty while after having made the decision, investing more may not be

too dependent on founders' dislike of novelty and change.

It should be noted that all the traits discussed still significantly explain R&D and investment even after accounting for a large set of other drivers. Moreover, it is remarkable that the effects related to these traits exhibit such pronounced patterns, considering that we looked at the investment decision of individuals who have already embarked on founding a firm, and thereby represent a group of people that is in general not hesitant to risk, change, or adventure (Runst and Thomä, 2022a). Taken together, our results illustrate that these personality attributes affect decisions on R&D at least as much as other investments. The main impact of founder personality at the extensive margin is in line with the idea that the inherent uncertainty related to R&D leaves more room for subjective assessments of returns and profitability. In particular, risk tolerance has been shown to mentally compensate for failure and loss potential, and openness requires structuring and developing the company in novel ways (Brandstätter, 2011), and therefore both of these traits are strongly associated with R&D decisions. However, there are also other psychometric similarities between decisions in R&D and tangible investments, with more agreeable and more neurotic founders less likely to invest in both. These results are robust to different model specifications. Especially, the main results are stable irrespective of the choice of the exclusion restriction included in the selection models.

These findings contribute to the discussion of why some firms engage in R&D and pursue a growth strategy, while others do not. The insight that the personality of the founder determines the degree to which new firms engage in R&D and invest in firm growth further contributes to the ongoing debate about structural versus intrinsic differences in startup performance and innovation between countries.

4.1 Implications and Limitations

In synthesis with the personality performance link documented in earlier work, studying the role of founder personality for R&D and investments contributes to a better understanding of the performance drivers in young, innovative companies.

These insights complement those from the meta-analyses by Brandstätter (2011) and Kerr et al. (2017) that demonstrated that there is a relationship between psychometric attributes and firm performance. Brandstätter (2011) suggests that risk propensity supports business foundation, nonetheless not necessarily business success. Our results may link to the higher innovation likelihood of firms that engage in R&D, but also to the inherent risk profile that such investment

bears. That is, while higher risk tolerance enables more R&D activities, it may also lead to a higher variance of returns. Kerr et al. (2017) summarize the trait openness to experience to be related to own originality but also an attraction to changing environments. This aligns with our results conveying that high openness levels produce a stronger R&D investment likelihood. Though only weakly significant and not persistently cross-validated at the intensive margin, the investment amount decision, expresses a negative association between R&D and openness, speaking to the taste for diversifying into many R&D projects instead of a low number but high volume R&D stimuli to the entrepreneur.

In earlier work, such as Lumpkin and Dess (1996), entrepreneurship and firm performance are conceived to evolve from a compound of individual, organizational, or environmental factors. Our study advances this concept by linking individual factors to specific firm strategic investments. The insight that individual personality explains investments even after other firm characteristics and the competitive environment are controlled for is informative for policy makers. It is paramount to know which founder types to reach when drafting entrepreneurial policy in the attempt to address a non-random founder selectivity. Previous research stressed that targeted policy instruments can foster entrepreneurial performance and indicate that entrepreneurial investments are indeed below the social optimum (Hottenrott and Richstein, 2020). Our finding further add to recent research on the role of decision maker personality for SME strategy. While Runst and Thomä (2022a) provided novel evidence on personality as a key determinant of a non-R&D innovation strategy, our results expand these insights to R&D and tangible investments as important strategic decisions.

In spite of all efforts, this study is not without limitations. First, we do not analyze the decision to become an entrepreneur, as our data covers founders. Despite personality traits being non-transient (Roccas et al., 2002), Kerr et al. (2017) raise the issue of endogenously strengthened personality traits after adopting an entrepreneurial role. To avoid confusion of exogenous metrics with endogenous outcomes, using pre- and post-founding information or entrepreneurial training records would make the exposition to interventions and personality's time variance observable. Second, entrepreneurial risk tolerance may be affected by personal, family's and friends' financial wealth which we cannot account for. Third, we explored only selected personality traits which may not represent fundamental aspects in an entrepreneurial context, such as cooperativeness, reciprocity, patience or trust. For this reason, we strongly encourage more extensive research on this topic to investigate other dimensions of personality, especially those that capture inter-human

behavior. Moreover, we did not shed light on team composition and how different founders' personalities may complement or nullify each other. Looking at personality in a within team setting might provide additional insights into the role of founder personality on entrepreneurial behavior. Ultimately, we did not deconstruct the nature of R&D into its components, although personality may play a different role for (basic) research as compared to development or for R&D activities, with particularly high social returns from, for instance, environmentally beneficial technologies. Future research may also explore the rates of return to R&D depending on founder personality. While we find that founders with higher openness to experience may invest higher amounts, it remains unclear whether these investments are indeed profitable. Acceleration of commitment and overconfidence may result in non-profitable efforts and waste of resources. The link between personality traits and these phenomena requires research beyond the scope of this study.

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Appendix

Table A1: Year distribution and annual pattern of firm characteristics

Observation year	Full sample		Employees	Firm age	R&D (exp.)	Tang. inv. (vol.)	Tangible assets
	Count	Share	Mean				
2017	3,654	69.57%	3	3	17,684	34,000	11,385
2018	1,598	30.43%	6	4	34,517	32,195	9,966
Total	5,252	100.00%	4	3	22,806	33,451	10,953

Table A2: Sector distribution and sectoral pattern of annual R&D and investment variables (variable means)

#	Sector	Full sample		R&D	R&D ()	R&D/empl.	Inv.	Inv. ()
		Count	Share	Mean				
1	Cutting-edge manufacturing	287	5.46%	0.484	70,193	14,126	0.641	31,125
2	High tech manufacturing	274	5.22%	0.609	77,673	13,200	0.639	75,692
3	Tech services	989	18.83%	0.313	23,705	5,470	0.665	28,619
4	Software	479	9.12%	0.532	61,060	11,906	0.595	13,063
5	Low tech manufacturing	504	9.60%	0.254	0.645	5,834	0.645	59,970
6	Knowledge-intensive services	511	9.73%	0.160	9,759	2,331	0.611	12,067
7	Other company services	417	7.94%	0.065	12,390	5,928	0.614	36,897
8	Creative services	393	7.48%	0.148	7,203	1,856	0.631	31,341
9	Other services	351	6.68%	0.054	1,056	505	0.613	46,607
10	Construction	549	10.45%	0.067	1,710	989	0.760	37,446
11	Retail	498	9.48%	0.092	7,001	997	0.570	20,961
	Total	5,252	100.00%	0.241	22,806	5,200	0.640	33,451

Table A3: Distribution of startups across German federal states

Federal state	Full sample		East Germany	
	Count	Share	Count	Share
Schleswig-Holstein	166	3.16%		
Hamburg	172	3.27%		
Lower Saxony	471	8.97%		
Bremen	48	0.91%		
North Rhine-Westphalia	1,269	24.16%		
Hesse	406	7.73%	East=0	
Rhineland-Palatinate	246	4.68%		
Baden-Würtemberg	629	11.98%		
Bavaria	844	16.07%		
Saarland	43	0.82%		
Berlin	247	4.70%		
Brandenburg	118	2.25%		
Mecklenburg-Western Pomerania	83	1.58%		
Sachsen	255	4.86%	East=1	
Saxony-Anhalt	103	1.96%		
Thuringia	152	2.89%		
Total	5,252	100.00%	711	13.54%

Table A4: Questions on entrepreneurial orientation and personality dimensions from the start-up panel survey (IAB/ZEW survey waves 2018 and 2019)

No.	Question	Item	Factor
	Entrepreneurial orientation[1]		
1	In order to achieve corporate goals even in uncertain situations, my company proceeds...		
a)	...rather cautiously, in a wait and see approach, in order to avoid wrong decisions.	$risk_1$	Risk tolerance
b)	...rather bravely and aggressively so as not to miss any business opportunities.		
2	My company has a strong inclination for projects with...		
a)	...low risk and thus normal but secure returns.	$risk_2$	
b)	...high risk and thus opportunities for very high returns.		
	Personality traits (OCEAN)[2]		
3	I am someone who is original and who brings up new ideas.	$open_1$	Openness
4	I am someone who values artistic experiences.	$open_2$	
5	I am someone who has vivid fantasies and a good imagination.	$open_3$	
6	I am someone who works thoroughly.	$consc_1$	Conscientiousness
7	I am someone who is rather lazy.	$consc_2$	
8	I am someone who gets things done effectively and efficiently.	$consc_3$	
9	I am someone who is communicative and talkative.	$extra_1$	Extraversion
10	I am someone who can get out and be sociable.	$extra_2$	
11	I am someone who is reserved.	$extra_3$	
12	I am someone who is at times a little rude to others.	$agree_1$	Agreeableness
13	I am someone who can forgive.	$agree_2$	
14	I am someone who is considerate and kind to others.	$agree_3$	
15	I am someone who worries often.	$neuro_1$	Neuroticism
16	I am someone who gets nervous easily.	$neuro_2$	
17	I am someone who is relaxed and can handle stress well.	$neuro_3$	

Answer options were self-ratings on a Likert scale from 1 to 5 with:
[1] 1: completely a), 2: rather a), 3: undecided, 4: rather b), 5: completely b)
[2] 1: does not apply to me at all, and 5: fully applies to me
[*] Items 7, 11, 12, and 17 have been reversely rescaled to align scale direction.

Table A5: Factor analysis of risk tolerance

	Eigenvalues
Factor1	1.387
Factor2	0.613

	Factor loadings
Item	Factor1
risk_1	0.622
risk_2	0.622

Table A6: Factor analysis of OCEAN (Personality traits)

	Eigenvalues
Factor1	2.803
Factor2	1.653
Factor3	1.635
Factor4	1.396
Factor5	1.121
Factor6	0.885
Factor7	0.815
Factor8	0.719
Factor9	0.673
Factor10	0.636
Factor11	0.592
Factor12	0.553
Factor13	0.542
Factor14	0.504
Factor15	0.472

	Factor loadings				
Item	Factor1	Factor2	Factor3	Factor4	Factor5
$open_1$	0.059	**0.740**	0.081	-0.119	-0.108
$open_2$	-0.162	**0.717**	-0.171	0.134	0.074
$open_3$	0.052	**0.796**	-0.019	-0.101	-0.029
$consc_1$	-0.091	-0.054	**0.820**	0.052	0.077
$consc_2$	0.054	-0.164	**0.661**	-0.026	-0.037
$consc_3$	-0.004	0.062	**0.784**	-0.112	-0.068
$extra_1$	**0.768**	0.071	0.025	0.162	0.064
$extra_2$	**0.792**	0.023	-0.006	0.136	0.094
$extra_3$	**0.745**	-0.126	-0.089	-0.236	-0.125
$agree_1$	-0.029	-0.155	-0.077	**0.784**	-0.159
$agree_2$	0.170	0.118	-0.063	**0.499**	-0.030
$agree_3$	0.112	0.049	0.093	**0.740**	0.068
$neuro_1$	0.007	0.026	0.131	0.035	**0.750**
$neuro_2$	0.012	-0.003	-0.061	-0.018	**0.778**
$neuro_3$	0.064	-0.151	-0.101	-0.230	**0.652**

Table A7: Cross-correlations of ROCEAN & dependent variables

		1	2	3	4	5	6	7	8	9	10	11
1	Risk tolerance	1.000										
2	Openness	0.127	1.000									
3	Conscientiousness	-0.072	0.203	1.000								
4	Extraversion	0.105	0.297	0.227	1.000							
5	Agreeableness	-0.105	0.186	0.234	0.004	1.000						
6	Neuroticism	-0.185	0.015	-0.044	-0.131	0.028	1.000					
7	R&D (binary)	0.215	0.132	-0.080	0.008	-0.066	-0.096	1.000				
8	ln(R&D exp.)	0.230	0.127	-0.083	0.011	-0.074	-0.101	0.984	1.000			
9	Investments (binary)	0.028	0.002	0.024	0.018	-0.050	-0.032	0.067	0.065	1.000		
10	ln(Investments)	0.051	0.007	0.025	0.026	-0.062	-0.039	0.089	0.097	0.966	1.000	
11	R&D per employee	0.108	0.062	-0.033	0.007	-0.038	-0.040	0.350	0.413	0.003	0.027	1.000

Table A8: Cross-correlations of ROCEAN & founder characteristics

		1	2	3	4	5	6	7	8	9	10	11
1	Risk tolerance	1.000										
2	Openness	0.127	1.000									
3	Conscientiousness	-0.072	0.203	1.000								
4	Extraversion	0.105	0.297	0.227	1.000							
5	Agreeableness	-0.105	0.186	0.234	0.004	1.000						
6	Neuroticism	-0.185	0.015	-0.044	-0.131	0.028	1.000					
7	Female	-0.034	0.033	0.044	0.048	0.066	0.062	1.000				
8	Founder age	-0.023	-0.001	-0.023	-0.102	0.056	0.004	0.056	1.000			
9	University degree	0.182	-0.005	-0.147	-0.047	-0.044	-0.118	0.060	0.210	1.000		
10	Industry experience	-0.079	-0.016	0.040	-0.061	0.036	0.027	-0.056	0.550	-0.046	1.000	
11	Serial entrepreneur	0.151	0.065	-0.100	-0.005	-0.047	-0.065	-0.041	0.264	0.179	0.103	1.000

Table A9: Cross-correlations of ROCEAN & firm characteristics

		1	2	3	4	5	6	7	8	9	10	11
1	Risk tolerance	1.000										
2	Openness	0.127	1.000									
3	Conscientiousness	-0.072	0.203	1.000								
4	Extraversion	0.105	0.297	0.227	1.000							
5	Agreeableness	-0.105	0.186	0.234	0.004	1.000						
6	Neuroticism	-0.185	0.015	-0.044	-0.131	0.028	1.000					
7	ln(employees)	0.106	-0.008	-0.024	0.052	-0.056	-0.024	1.000				
8	ln(tangible assets)	-0.002	0.017	-0.009	-0.003	-0.023	0.036	-0.099	1.000			
9	Limited company	0.190	0.010	-0.113	-0.039	-0.073	-0.123	0.267	-0.139	1.000		
10	Opportunity driven	0.090	0.035	-0.006	0.049	0.002	-0.068	0.018	0.001	0.059	1.000	
11	Team founder	0.081	0.014	-0.060	-0.018	0.007	-0.028	0.303	-0.028	0.289	0.043	1.000

Table A10:

Estimation results - Models: R&D and investment decision (ROCEAN as PFS)
Method: Heckman LASSO, non-penalized (ROCEAN not allowed as exclusion restriction)

	Models: R&D decision			**Models: Tangible investment decision**		
	Intensive margin	Extensive margin	Average marginal effects	Intensive margin	Extensive margin	Average marginal effects
Risk tolerance	0.239***	0.148***	0.034***	0.107***	0.012	0.004
	(0.045)	(0.025)	(0.006)	(0.024)	(0.021)	(0.007)
Openness	-0.099*	0.256***	0.059***	-0.029	0.044**	0.015**
	(0.052)	(0.026)	(0.006)	(0.024)	(0.020)	(0.007)
Conscientiousness	0.030	-0.054**	-0.012**	0.060**	0.030	0.010
	(0.041)	(0.024)	(0.006)	(0.024)	(0.020)	(0.007)
Extraversion	0.036	-0.023	-0.005	0.064***	-0.007	-0.002
	(0.042)	(0.024)	(0.006)	(0.023)	(0.020)	(0.007)
Agreeableness	-0.011	-0.066***	-0.015***	-0.051**	-0.079***	-0.027***
	(0.039)	(0.023)	(0.005)	(0.025)	(0.020)	(0.007)
Neuroticism	-0.019	-0.079***	-0.018***	-0.046**	-0.055***	-0.019***
	(0.040)	(0.023)	(0.005)	(0.023)	(0.019)	(0.007)
Female	-0.280**	-0.190***	-0.044***	-0.151**	-0.194***	-0.067***
	(0.115)	(0.065)	(0.015)	(0.069)	(0.051)	(0.017)
Founder age	0.019***	-0.003	-0.001		-0.010***	-0.004***
	(0.003)	(0.003)	(0.001)		(0.002)	(0.001)
University degree	0.111	0.391***	0.090***	-0.060	0.124***	0.043***
	(0.101)	(0.051)	(0.012)	(0.051)	(0.044)	(0.015)
ln(employees)	0.778***	0.175***	0.040***	0.893***	0.298***	0.102***
	(0.056)	(0.035)	(0.008)	(0.050)	(0.031)	(0.011)
Limited company	0.878***	0.454***	0.104***	0.208***	-0.143***	-0.049***
	(0.121)	(0.054)	(0.012)	(0.055)	(0.045)	(0.015)
Opportunity driven	0.230*	0.100	0.023		-0.018	-0.006
	(0.119)	(0.066)	(0.015)		(0.052)	(0.018)
Industry experience		-0.001	-0.000	0.009***	0.007***	0.002***
		(0.003)	(0.001)	(0.002)	(0.002)	(0.001)
Serial entrepreneur		0.078	0.018	0.086*	-0.126***	-0.043***
		(0.048)	(0.011)	(0.051)	(0.041)	(0.014)
ln(tangible assets)		0.009*	0.002*		0.016***	0.005***
		(0.005)	(0.001)		(0.004)	(0.001)
Team founder		0.074	0.017	-0.062	-0.006	-0.002
		(0.061)	(0.014)	(0.061)	(0.054)	(0.019)
Cohort FE	No	Yes	Yes	Yes	Yes	Yes
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes
Federal state FE	Yes	Yes	Yes	Yes	Yes	Yes
Survey wave FE	No	Yes	Yes	No	Yes	Yes
λ	-0.305***			-0.259***		
Observations	5,252	5,252	5,252	5,252	5,252	5,252

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.010$

Table A11:

Estimations results for R&D and investment decisions (LASSO-Heckmann, FE and ROCEAN traits allowed as exclusion restriction)

	Models: R&D decision			**Models: Tangible investment decision**		
	Selection estimation (twostep)		Average marginal effects	Selection estimation (twostep)		Average marginal effects
Risk tolerance	0.228***	0.138***	0.032***	0.104***	0.013	0.004
	(0.042)	(0.023)	(0.005)	(0.023)	(0.020)	(0.007)
Openness	-0.083*	0.255***	0.059***		0.043**	0.015**
	(0.047)	(0.025)	(0.006)		(0.020)	(0.007)
Female	-0.282**	-0.192***	-0.044***	-0.223***	-0.192***	-0.067***
	(0.115)	(0.065)	(0.015)	(0.068)	(0.051)	(0.018)
Founder age	0.019***	-0.003	-0.001	-0.004	-0.010***	-0.003***
	(0.003)	(0.003)	(0.001)	(0.003)	(0.002)	(0.001)
University degree	0.105	0.393***	0.091***		0.105**	0.037**
	(0.102)	(0.051)	(0.012)		(0.043)	(0.015)
ln(employees)	0.786***	0.176***	0.041***	1.001***	0.288***	0.101***
	(0.056)	(0.035)	(0.008)	(0.049)	(0.031)	(0.011)
Limited company	0.890***	0.453***	0.104***	0.144***	-0.143***	-0.050***
	(0.120)	(0.054)	(0.012)	(0.053)	(0.045)	(0.015)
Opportunity driven	0.237**	0.101	0.023		-0.027	-0.010
	(0.119)	(0.066)	(0.015)		(0.052)	(0.018)
Conscientiousness		-0.054**	-0.012**	0.072***	0.032	0.011
		(0.024)	(0.006)	(0.024)	(0.020)	(0.007)
Extraversion		-0.025	-0.006	0.061***	-0.005	-0.002
		(0.024)	(0.006)	(0.022)	(0.020)	(0.007)
Agreeableness		-0.064***	-0.015***	-0.086***	-0.083***	-0.029***
		(0.023)	(0.005)	(0.024)	(0.020)	(0.007)
Neuroticism		-0.078***	-0.018***	-0.063***	-0.050***	-0.017***
		(0.023)	(0.005)	(0.023)	(0.019)	(0.007)
Industry experience		-0.001	-0.000	0.013***	0.007***	0.002***
		(0.003)	(0.001)	(0.003)	(0.002)	(0.001)
Serial entrepreneur		0.080*	0.018*		-0.126***	-0.044***
		(0.048)	(0.011)		(0.041)	(0.014)
ln(tangible assets)		0.009*	0.002*		0.015***	0.005***
		(0.005)	(0.001)		(0.004)	(0.001)
Team founder		0.089	0.020	-0.102*	-0.028	-0.010
		(0.061)	(0.014)	(0.061)	(0.054)	(0.019)
Cohort		0.003	0.001	-0.122***	-0.139***	-0.049***
		(0.014)	(0.003)	(0.023)	(0.011)	(0.004)
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes
Federal state FE	Yes	Yes	Yes	Yes	Yes	Yes
Survey wave FE	No	Yes	Yes	No	Yes	Yes
λ		-0.248***			0.477***	
Observations	5,252	5,252	5,252	5,252	5,252	5,252

Standard errors in parentheses (clustered at firm level)
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.010$

Table A12: Estimation results for R&D and investments estimated as standard selection model (Heckman) with researcher-based exclusion restrictions

	Models: R&D decision			**Models: Tangible investment decision**		
	Intensive margin	Extensive margin	Average marginal effects	Intensive margin	Extensive margin	Average marginal effects
Risk tolerance	0.129***	0.136***	0.032***	0.097***	0.012	0.004
	(0.046)	(0.023)	(0.005)	(0.024)	(0.020)	(0.007)
Openness	-0.260***	0.257***	0.060***	-0.039	0.047**	0.016**
	(0.065)	(0.025)	(0.006)	(0.025)	(0.021)	(0.007)
Conscientiousness	0.067	-0.059**	-0.014**	0.062**	0.028	0.010
	(0.045)	(0.024)	(0.006)	(0.025)	(0.020)	(0.007)
Extraversion	0.056	-0.023	-0.005	0.066***	-0.009	-0.003
	(0.044)	(0.024)	(0.005)	(0.025)	(0.020)	(0.007)
Agreeableness	0.034	-0.065***	-0.015***	-0.036	-0.082***	-0.028***
	(0.042)	(0.023)	(0.005)	(0.022)	(0.020)	(0.007)
Neuroticism	0.031	-0.078***	-0.018***	-0.034	-0.056***	-0.019***
	(0.047)	(0.024)	(0.006)	(0.024)	(0.020)	(0.007)
Female	-0.125	-0.188***	-0.044***	-0.115*	-0.190***	-0.065***
	(0.141)	(0.065)	(0.015)	(0.066)	(0.052)	(0.018)
Founder age	0.021***	-0.002	-0.001	0.000	-0.010***	-0.003***
	(0.005)	(0.003)	(0.001)	(0.003)	(0.002)	(0.001)
Industry experience	-0.001	-0.001	-0.000	0.009***	0.007***	0.002***
	(0.005)	(0.003)	(0.001)	(0.003)	(0.002)	(0.001)
Serial entrepreneur	-0.008	0.080	0.019*	0.115**	-0.121***	-0.041***
	(0.091)	(0.049)	(0.011)	(0.050)	(0.042)	(0.014)
ln(employees)	0.679***	0.166***	0.039***	0.828***	0.295***	0.101***
	(0.070)	(0.035)	(0.008)	(0.038)	(0.034)	(0.011)
Limited company	0.511***	0.452***	0.105***	0.239***	-0.132***	-0.045***
	(0.150)	(0.056)	(0.013)	(0.054)	(0.046)	(0.016)
Opportunity driven	0.149	0.101	0.024	0.021	-0.015	-0.005
	(0.138)	(0.067)	(0.016)	(0.061)	(0.054)	(0.018)
Team founder	-0.114	0.072	0.017	-0.098	-0.006	-0.002
	(0.110)	(0.061)	(0.014)	(0.064)	(0.055)	(0.019)
University degree		0.350***	0.081***		0.105**	0.036**
		(0.052)	(0.012)		(0.043)	(0.015)
ln(tangible assets)		0.008*	0.002*		0.015***	0.005***
		(0.005)	(0.001)		(0.004)	(0.001)
Cohort FE	No	Yes	Yes	No	Yes	Yes
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes
Federal state FE	Yes	Yes	Yes	Yes	Yes	Yes
Survey wave FE	Yes	Yes	Yes	Yes	Yes	Yes
ρ	-1.004***			-0.505***		
λ	-1.247***			-0.593***		
$ln(\sigma)$	0.491***			0.241***		
Observations	1,268	5,252	5,252	3,359	5,252	5,252

Standard errors in parentheses (clustered at firm level)
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.010$