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Small business owners as gatekeepers of knowledge? Personality traits & modes of innovation

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Abstract:

Previous research has established that certain personality traits represent predictors of start-up activity. We argue that similar cognitive processes that affect entrepreneurship also play a role in firm-level innovativeness. For example, openness to novelty can be regarded as a key component of entrepreneurial alertness in terms of both business creation and the generation of innovations within existing businesses. Based on a large survey of less R&D-intensive SMEs from Germany, we show that certain Big Five personality traits as well as certain personality prototypes of business owners are positively related to innovation activity. More importantly, this relationship depends on the mode of innovation, where companies operating under the DUI mode (Doing-Using-Interacting) seem to benefit in particular from certain owners' personality characteristics. In addition, we present evidence that complementarities between entrepreneurs' personality traits exist in terms of self-selection into the DUI mode. To explain our findings, we argue that the personality characteristics of small business owners affect whether or not absorptive capacity can mediate between external knowledge and firm-level innovativeness.

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Keywords: Innovation, Modes of innovation, Absorptive capacity, Personality Traits, Big Five, SMEs

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1. Introduction

The role played by in-house research and development (R&D) for innovation in small and medium-sized enterprises (SMEs) is a matter of ongoing debate. On the one hand, it can be argued that smaller firms face systematic disadvantages in terms of R&D compared to larger firms, which may prevent them from realizing their innovative potential (Acs and Audretsch, 2005; Cohen, 1995; Nooteboom, 1994; Ortega-Argilés et al., 2009; Rothwell, 1989). On the other hand, the assumption that R&D is a pivotal source of innovation is questioned by studies showing that SMEs can be successful in innovation without conducting internal R&D. This implies that non-R&D-related sources of knowledge hold strong relevance for smaller firms (Baldwin and Gellatly, 2003; Hervas-Oliver et al., 2011; Rammer et al., 2009; Thomä and Zimmermann, 2020). One notion that is agreed upon is the fact that external knowledge inflows can compensate for in-house resource constraints, and therefore that they are crucial to a SME's capacity for innovation, irrespective of whether own R&D is conducted or not (Baldwin and Gellatly, 2003; Bruns-wicker and Vanhaverbeke, 2015; Hewitt-Dundas, 2006; Jong de and Marsili, 2006).

The concept of 'absorptive capacity' holds special interest in this regard, reflecting the ability to identify, absorb and exploit external knowledge (Cohen and Levinthal, 1989, 1990). Traditionally, the absorptive capacity of a firm is seen as being closely related to prior R&D efforts. Consequently, there is a R&D bias in the scholarly research on absorptive capacity, with a special emphasis given to high technology contexts (Lane et al. 2006). By contrast, the innovation performance of less R&D-intensive SMEs is known to be strongly based on external knowledge sourcing and external partnerships to compensate for the lack of R&D competencies (e.g. Rammer et al., 2009; Thomä and Zimmermann, 2020). This casts doubt on whether R&D accounts for the entire absorptive capacity of innovating SMEs, especially in terms of less R&D-intensive companies. For example, based on a sample mainly comprising SMEs, the results of Som et al. (2015) imply that highly R&D-intensive and non-R&D-intensive firms are equally likely to recognize and implement novel technological knowledge from external sources. This implies that there is little difference in the level of absorptive capacity between these two types of innovating firms. To give another example, Hervas-Oliver et al. (2012) examine low- and medium-tech SMEs, showing that human resources and other non-R&D innovation activities are much better predictors of the sourcing of external technological knowledge than expenditure on in-house R&D.

Against this background, the results of Moilanen et al. (2014) point to a research gap regarding the absorptive capacity of non-R&D-intensive SMEs. Their empirical investigation into the link between external knowledge, absorptive capacity and innovative performance implies that external knowledge inflows directly affect the innovation success of non-R&D-intensive SMEs with no mediating effect of absorptive capacity. Somewhat surprised by this result, the authors conclude that there is a need to develop better measures of absorptive capacity in the context of less R&D-intensive knowledge environments. In our view, one possible explanation for the paradoxical finding of Moilanen et al. (2014) is that the key role of the small business owner in absorbing externally-available knowledge has been overlooked.

The owner is in a critical position, especially in smaller-sized firms, as he/she is mostly solely responsible for all day-to-day management activities. Accordingly, innovation in smaller-sized firms is strongly shaped by the personal characteristics of the owner-manager, with relative strengths and weaknesses vis-à-vis larger firms that may arise from such a person-centered business culture (Nooteboom, 1994; Rothwell, 1989). This is particularly true in terms of absorptive capacity. While considering larger firm environments, Cohen and Levinthal (1990) point to the relevance of certain 'gatekeepers' as key drivers of a firm's absorptive capacity. These are individuals "who stand at the interface of either the firm and the external environment or at the interface between subunits within the firm" (p. 132). The gatekeeper's primary tasks are to identify relevant external knowledge and communicate the underlying technological information within the firm, so that organizational absorptive capacities can finally emerge. When transferring this argument to the specific case of SMEs, one could easily expect owners to be important knowledge gatekeepers in terms of their firm's absorptive capacity. Hence, we hypothesize that the personal characteristics of the small business owner affect whether or not absorptive capacity can mediate between external knowledge and firm-level innovativeness in less R&D-intensive SMEs (Hypothesis 1).

In line with Cohen and Levinthal's main argument that the impact of gatekeepers on a firm's absorptive capacity comprises external knowledge sourcing *and* subsequent internal knowledge dissemination, our contribution is twofold. *First*, based on a broad sample of German SMEs, we use the Big Five personality traits (extraversion, agreeableness, conscientiousness, emotional stability/neuroticism and openness to experience; see Digman 1990, Costa and McCrae 1995) to account for the personal characteristics of small business owners, which are seen as a key component of a firm's absorptive capacity. The effect of the Big Five on entrepreneurship is well documented in the literature (e.g. see Obschonka and Stuetzer, 2017; Ciavarella, 2004; Caliendo et al., 2014; Zhao and Seibert, 2006; McCrae and Costa, 2008; Zhao et al., 2010; also see Rauch and Frese, 2007). To our knowledge, the relationship between the Big Five personality traits and external knowledge sourcing has not yet been examined, with the notable exception of Marcati et al. (2008), who demonstrate certain correlations between Big Five traits and the intention of SME entrepreneurs to adopt innovations. We link the Big Five model to the concept of absorptive

capacity by employing a ‘traits vs. type approach’. Accordingly, the complementarities between different personal traits (Asendorpf et al., 2001; Asendorpf, 2002; Herzberg and Roth, 2006; Hofstee, 2002) are acknowledged. Consequently, we hypothesize that Big Five traits not only separately affect the absorptive capacities of SMEs, but rather the aspect of personality prototypes – i.e. the combination of certain Big Five traits within the owner’s personality – should also hold relevance (Hypothesis 2).

Second, in addressing the case of non-R&D innovation and the key point that an individual’s absorptive capacity needs to be transformed to organizational absorptive capacity to enhance innovativeness at the company level, we make use of the STI/DUI concept proposed by Jensen et al. (2007). According to these authors, there are two ideal modes of learning that are integrated and combined by innovating firms to varying degrees: the Science, Technology and Innovation (STI) mode – dominated by codified knowledge generated from formal processes of R&D – and the Doing, Using and Interacting (DUI) mode, which is dominated by informal processes of interactive learning. Innovation activities of less R&D-intensive SMEs are strongly shaped by the DUI mode (Kirner et al., 2015; Thomä, 2017). It is interesting to note that the DUI mode is described as being based on a general culture of open communication within the firm, and the experience-based know-how of employees (Apanasovich, 2016; Asheim and Parrilli, 2012a; Jensen et al., 2007; Parrilli et al., 2016). Cohen and Levinthal (1990) have already argued that an organization’s absorptive capacity not only depends on the gatekeeper’s capabilities in terms of monitoring the external environment and fostering internal communication, but also the know-how of those employees to whom the external knowledge is transmitted. At the same time, the DUI mode is marked by a distinct openness to external knowledge sources such as customers, suppliers and competitors (Apanasovich, 2016; Asheim and Parrilli, 2012a; Jensen et al., 2007; Parrilli et al., 2016), providing a hint that distinct non-R&D absorptive capacities indeed exist. Under such circumstances, a small firm’s absorptive capacity should be less dependent on prior R&D efforts. Instead, we assume the small business owner to be the key person who mediates and triggers DUI mode learning and thus acts as a centralized knowledge gatekeeper who ensures the organizational absorptive capacity of less R&D-intensive SMEs (Hypothesis 3). To validate this hypothesis, we empirically examine whether the personality traits/types of small business owners are more strongly related to self-selection into the DUI mode than the R&D-oriented STI mode of innovation.

The remainder of this paper is structured as follows. Section 2 provides a discussion of the literature to further validate our hypotheses, followed by a presentation of our data and a preparation of variables (Section 3). The regression results are discussed in Section 4, before the final section concludes with implications for management, policy and research.

2. Background

2.1. Personality traits: The Big Five model as a standard in entrepreneurship

Following Kirzner (1979, 1985), entrepreneurship represents an element of human agency. In the realm of business formation, entrepreneurs display alertness to pecuniary profit opportunities. At its core, entrepreneurial action is a discovery of hitherto unknown possibilities, and thus entrepreneurs perceive and implement novelty – whether in the form of new products and services, or internal processes and organizational improvements – foreshadowing its link to innovation. As the aforementioned empirical studies on the Big Five traits demonstrate, a person who is open to new experiences seems to be particularly well suited to recognize the value of such novel entrepreneurial opportunities, as he/she is likely prone to engage in creative thinking and explore new avenues of doing things. Moreover, entrepreneurs only rarely act in isolation (Sarasvathy, 2008). Instead, most businesses are embedded in networks of financiers, suppliers, customers, etc. An extroverted person would consequently be more likely to actively engage in creating and maintaining such networks. Accordingly, personal characteristics of entrepreneurs are at the heart of understanding the phenomenon of entrepreneurship (Zhao and Seibert, 2006).

In this context, the Big Five model of personality has become a standard measurement approach. The Big Five Inventory (BFI) was created as a 44-item questionnaire to measure the five personality traits of extraversion, agreeableness, conscientiousness, neuroticism (or emotional stability as its opposite pole) and openness (John et al., 1991). According to John et al. (2008), there is a broad consensus in the field of psychology that the Big Five “can represent the various and diverse systems of personality description in a common framework” (John et al., 2008, 116).

Previous research has established robust links between the Big Five and the propensity to start a business. For example, Caliendo et al. (2014) find that certain Big Five traits (openness to experience, extraversion, and emotional stability) as well as risk tolerance, locus of control, and trust increase the likelihood of entry into self-employment. Obschonka and Stuetzer (2017) confirm the importance of the two Big Five traits of openness and extraversion in the context of entrepreneurship.

2.2. *Personal traits and innovation: Applying the Big Five model to a new context*

Cognitive processes of entrepreneurial action are similar to the cognitive processes of innovation. Schumpeter (1934, 1965) argued that any form of innovation (and technological change) stems from entrepreneurial action. In this regard, innovation and entrepreneurship are strongly related. Moreover, the owner-entrepreneur does not necessarily cease to act innovatively once the business is in place. In fact, any company requires “constant deliberate adjustments, by new dispositions made every day in the light of circumstances not known the day before, by B stepping in at once when A fails to deliver” (Hayek, 1945). Business owners engage in entrepreneurial and innovative acts after start-up, as they search for and implement solutions to a number of practical problems. For example, owners introduce new internal processes and organizational improvements, which may or may not result in new or significantly improved products and services. We therefore surmise that since the Big Five personality traits affect the likelihood of starting a business – which represents an innovative act in itself – the entrepreneur’s personality traits should also affect his/her innovativeness at a later stage of a firm’s life span. Some evidence in this regard is provided by the study of Marcati et al. (2008). These authors use a small survey data set (N=41) and show that SME owners’ innovativeness positively correlates with the Big Five personality traits of openness to experience and extraversion, as well as negatively correlating with conscientiousness and agreeableness.

Nevertheless, the empirical literature is largely silent on the relationship between an owner’s personality and innovativeness at the company level. One exception is the study of Ahn et al. (2017). Their results show that the decision of SMEs to adopt open innovation practices is affected by the personal characteristics of their Chief Executive Officers. To further delve into this topic, we employ the Big Five personality taxonomy to measure the psychological basis of an owner’s absorptive capacity.

2.3. *Big Five traits and their potential complementarities in terms of absorptive capacity*

Big Five traits can be related to behaviors that increase the absorptive capacity of a small business owner to access valuable external knowledge and optimally transmit and communicate this knowledge within his/her firm. For example, the results of Marcati et al. (2008) imply that an owner who scores higher on extraversion and openness achieves higher levels of external knowledge sourcing. Apart from this, openness to experience is closely linked to creativity and innovation, thereby making entrepreneurs with a higher degree of openness much more likely to monitor their external environment for novel ideas and promising technologies (Sung and Choi, 2009; Zhao and Seibert, 2006).

Moreover, higher scores on agreeableness, conscientiousness and emotional stability may put small business owners in a better position to communicate and transmit the external knowledge inflows within their company (for the following discussion, see again Sung and Choi, 2009; Zhao and Seibert, 2006). Agreeableness enhances interaction and cooperative relationships within firms, as it implies that the entrepreneur trusts his/her employees, appreciates their ideas and generally fosters communication or mutual support between employees in the context of innovation. Thus, the internal communication process required to shift absorptive capacity from an individual to an organizational level should benefit when the owner is agreeable. By contrast, conscientiousness relates to an entrepreneur’s task performance in term of organization, self-discipline and goal accomplishment. While being negatively correlated with individual creativity and innovativeness (see Marcati et al. 2008), a higher degree of conscientiousness may be rather helpful for entrepreneurs when firm-internal processes must be adapted to make valuable external knowledge applicable within the firm (i.e. the internal side of absorptive capacity). This should hold true in particular because effective employee engagement in innovation often requires clear workplace goals set by the management (Billett, 2012). Finally, emotionally stable entrepreneurs who are self-confident and resilient should be more likely to think positively about their tasks and other people. Hence, the owner’s higher degree of emotional stability should be a favorable precondition for successfully triggering informal processes of interactive learning within the firm. Moreover, employees are probably more likely to support innovative changes within their working environment when the personality of their owner-manager radiates calmness and optimism.

The preceding paragraph already implies that several Big Five traits may be complementary, in the sense that certain synergies between personality traits exist in the context of absorptive capacity. For example, while emotional stability and openness to experience may affect absorptive capacity separately, the combination of a high degree of emotional stability and openness could conceivably exceed the sum of the two separate effects. In other words, the mutual interplay of several traits could be more important than the effects of single traits. Person-oriented analyses of the Big Five traits focus on such configurations within an individual to describe distinct personality types (e.g. Asendorpf et al., 2001; Boehm et al., 2002; Fruyt et al., 2002; Herzberg and Roth, 2006; Schnabel et al., 2002), thereby overcoming the traditional variable-focused perspective of research on the Big Five model. Several studies have employed cluster analysis techniques and Q-sorts to show that there are at least three major Big Five prototypes at the individual level: resilient, over-controllers, and under-controllers (for an overview, see Asendorpf, 2002). While acknowledging that our sample comprises a particular sub-group of the overall

population – i.e. owners of less R&D-intensive SMEs – the present paper adds to this discussion by clustering firms according to the Big Five traits of their owners. The underlying assumption is that a person-oriented approach may be better suited to measure the psychological basis of a small business owner’s absorptive capacity.

2.4. DUI mode learning: From individual to organizational absorptive capacity

To grasp the important relationship between the individual and organizational level of absorptive capacity, we refer to the DUI mode of innovation. In contrast to the STI mode of innovation – which is based on in-house R&D, scientifically-trained personnel and external sources of codified knowledge – the DUI mode is marked by experience-based know-how embodied in people and informal (interactive) processes of learning within and outside innovating firms.

The inward-looking components of the DUI mode can be regarded as a general prerequisite for successful innovation at the company level, since corresponding in-house competencies are important for R&D- and non-R&D-performing firms alike (Thomä, 2017). One advantage of the DUI perspective is that it captures the organizational dimension of firm-level innovation. Prior studies have shown that DUI mode learning is closely related to changes in organizational procedures/structures and the knowledge gained from such processes (Jensen et al., 2007; Parrilli and Alcalde Heras, 2016). An organizational culture of learning therefore forms the internal foundation of the DUI mode, implying that an innovating firm with strong DUI mode competencies is a striking example of a learning organization (Asheim and Parrilli, 2012b). In this sense, a number of empirical studies use human resource management tools and teamwork practices as indicators of internal DUI interaction, since management authorities trying to consciously stimulate the internal exchange of knowledge often rely on such organizational mechanisms (e.g. Apanasovich, 2016; Jensen et al., 2007; Lee and Miozzo, 2019; Parrilli and Elola, 2012; Thomä and Zimmermann, 2020). Against this background, we expect DUI mode competencies to be at the core of what Zahra and George (2002) called the transformation of “potential” absorptive capacities into “realized” ones at the firm level. To account for this, in the present paper we empirically separate innovating SMEs according to their dominant mode of learning by means of cluster analysis. On this basis, we can examine whether a small business owner’s absorptive capacity is more likely to mediate the relationship between external knowledge sourcing and firm-level innovativeness if strong DUI mode competencies are in place.

3. Data and preparation of variables

3.1. Data set

In January 2019, in cooperation with three chambers of skilled crafts, we sent 17,000 letters to SMEs¹ located in the German federal state of Saxony, eventually receiving 1,928 replies (response rate 11.3%). Our focus on the skilled crafts sector ensures that our sample mostly comprises less R&D-intensive SMEs, as German craft enterprises typically operate in less R&D-intensive manufacturing and services industries (Thomä, 2018).

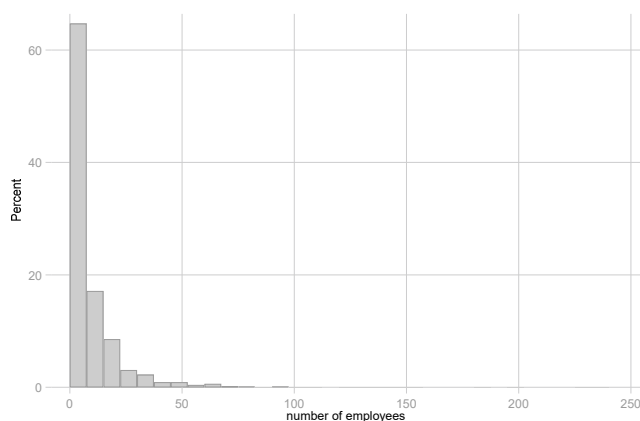
We primarily stratified the sample by the three crafts chamber districts, in each case randomly drawing from the official company registries. Moreover, we successfully strove to obtain a minimum number of 30 replies for each of the following trade groups in the German skilled crafts sector in each region: main construction trades, finishing trades (installation and completion), trades for industrial needs, automobile trades, foodstuffs trades, health trades, and trades for private needs.

As expected, the main survey round did not yield 30 completed questionnaires in all regions in the case of health trades and foodstuffs trades. Thus, crafts chamber employees called all companies in these trade groups that received a questionnaire but did not answer by phone to request their cooperation. Moreover, we randomly drew additional companies from the official registries (which did not receive a letter in the first wave) to send out a second wave of questionnaires in the case of health trades.

The sample mostly contains smaller-sized SMEs, which is unsurprising given our focus on the skilled crafts sector (see Figure 1). There are only 53 companies with more than 49 employees. When comparing the company size of the sample and the overall population (Table A1 in the appendix), we can see that larger companies are slightly overrepresented in our data set, as smaller firms are known to have a lower response likelihood.

¹ Defined according to the SME definition set by the European Union (i.e. an upper threshold of 249 employees).

Figure 1. Histogram of company size in the sample



The questionnaire is typically structured, covering information on general company characteristics, purchasing and sales, investment and innovation, cooperation with external partners, digitalization and personal characteristics of the company owner. In particular, we included several binary questions regarding innovation output. Firms were asked whether they had brought to market new or significantly improved products or services, or introduced new or significantly improved processes during the last three years. In line with the latest version of the Oslo Manual (OECD/Eurostat 2018), we also asked whether they had implemented innovation-related digitalization measures in the last three years regarding improved internal business processes, the development of new products/services, new business models, improved production/service provision, or the acquisition of new customer bases. If any of the former questions was answered affirmatively, we coded our innovation variable as one, and zero otherwise.

The questionnaire also contained information on the existence of in-house R&D activity during the previous three years as a pivotal source of innovation. Apart from this, it included twelve Likert-type questions (five-point scale) on the importance of several (internal and external) non-R&D sources of innovation, such as employee creativity, the scope for employees to develop new ideas, learning from customers, suppliers, universities, etc., which will enter into our cluster analysis regarding modes of innovation (see Section 3.2).

In addition, the survey contained a brief, ten-item construct of the Big Five personality domains of extraversion, agreeableness, conscientiousness, emotional stability/neuroticism and openness to experience on a seven-point Likert scale (Gosling, 2003; Rammstedt et al., 2007), which was constructed to allow the inclusion of personality aspects in cross-disciplinary research settings. The BFI-10 scales retain significant levels of reliability and validity compared with longer versions such as the BFI-44 (Rammstedt et al., 2007). In the present paper, in each case exactly two items are utilized to generate one of the trait variables on a fourteen-point scale. These five variables are used in the cluster analysis concerning potential personality prototypes among company owners (Section 3.2).

3.2. Cluster analysis: Preparing variables for regression analysis

Sources of innovation such as in-house R&D, scope for employees' new ideas or learning from customers and suppliers must not be seen as mutually-exclusive categories. Instead, combinations of learning mechanisms form distinct modes of innovation at the company level, such as DUI and STI (see sections 1 and 2). Cluster analysis can be used to sort firms into these modes of innovation for all companies that report innovating behavior according to our innovation definition above. As factorized variables lead to more robust clustering than using original items (Hair et al., 1998), we condense the twelve variables on non-R&D sources of innovation to a four-factor solution (see Table 1), which accounts for 65% of the total variance. Both Bartlett's test of sphericity (Chi-square = 5697.0, $p < 0.001$) and the Kaiser-Meyer-Olkin Measure of Sampling Adequacy ($KMO = 0.802$) suggest that the twelve items are sufficiently correlated to apply factor analysis. We employ the latent root criterion (eigenvalue > 1) as well as parallel analysis (Horn, 1965) via a scree plot, which represents an improvement over the eigenvalue rule (Humphreys and Montanelli, 1975).

The four external innovation sources of (1) trade press/media/internet, (2) trade fairs, (3) chambers/trade associations/guilds, and (4) laws/regulations load highly on the first factor. Learning from producers/suppliers also shows a relatively strong loading in this case (see Table 1). Hence, we label the first factor as 'applied external knowledge' (F1). This result shows that companies that seek information on recent technological or organizational developments in specialized journals also seem to search for relevant business information at trade fairs, they utilize the consulting services provided by their chamber, and they are alert to new regulatory requirements. Factor 1 therefore points to a certain openness towards application-oriented industry knowledge. By contrast, the variables of employee creativity and scope for employees to develop new ideas as well as – to a lesser extent – hiring

new staff load on the second factor, which we label ‘internal experiential knowledge’. Hence, companies that rely on their employee creativity to generate innovative ideas also seem to grant a higher degree of employee autonomy. Companies scoring high on the second factor are likely characterized by flat hierarchies and flexible organizational structures, which is contrasted by centrally-coordinated innovation activities in which employees only execute a previously-laid-out plan.

Table 1. Loadings from principal component factoring after varimax rotation (non-R&D sources of innovation)

Variable	F 1	F 2	F 3	F 4	Uniqueness
	Applied external knowledge	Internal experiential knowledge	External STI knowledge	Value chain knowledge	
Employee creativity		0.919			0.129
Scope for developing new ideas		0.910			0.133
Customers/clients				0.806	0.310
Suppliers/Producers	0.340			0.666	0.428
Competitors				0.689	0.408
Hiring new staff		0.394	0.558		0.461
Universities/other research institutis			0.858		0.231
R&D service providers/consultancy firms/marketing firms			0.818		0.263
Trade press/media/internet	0.731				0.391
Trade fairs	0.669				0.472
Chambers/trade associations/guilds	0.704				0.433
Laws/regulations	0.591				0.561

Notes: Only factor loadings > 0.3 are displayed here.

The third factor (F 3; ‘External STI knowledge’) shows high factor loadings on the variables (1) hiring of new staff, (2) universities/other public research institutes, and (3) external R&D service providers/consultancy firms/marketing firms. We interpret this factor as signifying the degree of external STI-based interaction, where the latest science-based knowledge is absorbed by (1) hiring key employees (likely university graduates), (2) engaging external R&D services or consultancy firms or (3) cooperating with universities, which we would mostly expect to see in larger SMEs. Finally, the fourth factor (F 4) elucidates the fact that SMEs often access external (DUI-based) knowledge through the value chain (Paton and McLaughlin, 2008; Fitjar and Rodríguez-Pose, 2013; Haus-Reve et al. 2019). Companies that receive innovation stimuli from customers also receive them from suppliers as by observing competitors. Hence, the fourth factor is labeled ‘Value chain knowledge’.

We follow Thomä and Zimmermann (2020) by employing hierarchical clustering to generate modes of innovation as well as assigning one such mode to each firm. The clustering variables are the existence of in-house R&D and the metric factor scores of our factor variables on non-R&D sources of innovation (standardized to a mean of 0 and a standard deviation of 1). Ward’s algorithm with squared Euclidean distance as the measure of similarity led to a four-cluster solution (see Table 2). A visual inspection of the dendrogram and two-cluster stopping rules (Calinski/Harabasz pseudo-F index and Duda-Hart index) was used to decide the number of clusters.

According to the cluster solution, companies in the first cluster (C1) are marked by a below-average share of in-house R&D and they are very unlikely to source external STI knowledge. This prompts us to assume that the DUI mode holds particular importance in case of C1. Indeed, companies in C1 are likely to learn from applied external knowledge, as factor F1 lies almost one standard deviation above the mean, with a strong reliance on experiential employee knowledge (F2 = 0.505). This relatively high degree of openness is validated by the higher degree of innovation-related cooperation in comparison to groups C2 and C3 (see Table 2). Therefore, the first cluster is labeled as the ‘open DUI group’.

The second group of companies (C2) also strongly rely on experiential knowledge (F2 = 0.624) but are much less open to external sources of applied external knowledge (-0.902). No strong emphasis on in-house R&D can be observed (the corresponding share corresponds to the sample average). Value chain knowledge seems to play a certain role (F4 = 0.113), whereas companies relatively seldom use external STI knowledge. Moreover, innovation cooperation with external partners rarely takes place in this group of SMEs (0.045). Thus, C2 can also be understood as resembling the DUI mode of innovation, although such firms are much more inward-focussed than in case of C1. Therefore, we label the second group as the ‘closed DUI group’.

Firms in C3 are innovative, even though they do not report being strongly stimulated by any of the sources of innovation in the questionnaire. In fact, they do not rely on internal experiential knowledge, which is more than one standard deviation below the mean ($F3 = -1.439$), whereas they score about average regarding applied external knowledge and STI sources of external knowledge. However, there is evidence in C3 of some influence of value chain knowledge on innovation, which brings the corresponding firms closer to the DUI mode ($F4 = 0.161$), even though the absolute effect size is low. Finally, in-house R&D holds practically no importance in the third group. Firms in C3 are also much smaller in size than those of the other three groups (6.6 employees on average). We label C3 as ‘Low learning’, following Thomä (2017), whose cluster solution of innovation modes yields a group with similar characteristics. The impact of value chain knowledge can be interpreted as an indicator of DUI innovation. It can be surmised that the smaller firms in this group take their very first steps in developing DUI competencies. On the other hand, the fact that no single factor seems to influence the innovation activity in this group in a quantitatively significant manner points to the existence of unknown factors that drive this mode of innovation.

Table 2. Four-cluster solution (modes of innovation)

	Overall mean	C1	C2	C3	C4	Chi2		
		Open DUI	Closed DUI	Low learning	STI/DUI			
		<i>Cluster solution in terms of the clustering variables</i>						
R&D	0.199	0.159	0.194	0.070	0.281	37.187	***	
Applied knowledge (F1)	0.068	0.848	-0.902	-0.091	0.284	409.159	***	
Internal experiential Knowledge (F2)	0.122	0.505	0.624	-1.439	0.273	418.520	***	
External STI knowledge (F3)	0.083	-0.817	-0.451	-0.249	1.063	629.502	***	
Value chain knowledge (F4)	0.048	-0.282	0.113	0.161	0.147	29.921	***	
		<i>Validating the Cluster Solution</i>						
# Employees	12.522	9.792	14.585	6.591	15.296	71.695	***	
Overall technical state of the plant and machinery, furniture and fixtures (compared to competitors)^a	2.300	2.344	2.432	2.418	2.136	22.058	***	
Innovation cooperation with external partners (1/0)	0.100	0.115	0.045	0.058	0.143	20.141	***	
N		226	242	172	398			

Notes: The table displays mean values of the factor variables (F1-F4), additional company characteristics for validation, and statistical significance of cluster differences (***)significance level of 1 percent, Kruskal-Wallis test with tie, Pearson's chi-square test). Factors F1- F4 have a mean value close to zero and a standard deviation of one.

^a From 1 (state-of-the-art) to 5 (completely out-of-date)

Finally, firms in C4 share a relatively strong emphasis on in-house R&D (the above-average share amounts to 0.281). Moreover, they are positively affected by all factors on non-R&D sources of innovation. They display some DUI characteristics as they have an above-average likelihood of relying on internal experiential knowledge ($F2 = 0.273$) and they are somewhat open to applied external knowledge ($F1 = 0.284$), although both aspects are less developed compared to the open DUI group (C1). Moreover, firms in cluster C4 also receive some external stimuli through value chain knowledge ($C4 = 0.147$). However, apart from the relatively strong emphasis on in-house R&D, the most distinctive characteristic of C4 can be found in its considerable reliance on external STI knowledge, because factor F3 is more than one standard deviation above the mean. Both aspects indicate a particularly high level of technological innovativeness, which is validated by the fact that firms in C4 are the largest in size on average (employees > 15) and they are most likely to report being engaged in innovation-related activities. Against this background, the fourth group is labelled the ‘STI/DUI group’.

In analogy to the clustering of innovation sources, personality traits can also be grouped into certain combinations of traits that frequently occur within individuals. Distinct trait combinations – or “personality prototypes” – have been detected by means of cluster analysis in the realm of personality psychology (see Asendorpf et al., 2001; Boehm et al., 2002; Fruyt et al., 2002; Herzberg and Roth, 2006; Schnabel et al., 2002). We follow standard procedure by applying Ward’s hierarchical cluster analysis based on the Big Five traits followed by a non-hierarchical (k-means) cluster analysis to optimize the cluster solution.² When using general samples of the population,

² We did not perform this two-step procedure in the case of innovation sources (see above). Hierarchical clustering without additional k-means

most studies yield the three prototypes of ‘resilient’, ‘ego over-controllers’, and ‘ego under-controllers’ (see Section 2.3).³ Resiliency refers to the ability “to respond flexibly, rather than rigidly to changing situational demands, particularly stressful situations. Ego control refers to the tendency to contain versus express emotional and motivational impulses (strong control vs. weak control)” (Asendorpf, 2001, 175). Both over- and under-controllers are related to lower levels of resiliency. Over-controllers display a tendency towards being inhibited, shy, having lower social self-esteem and more loneliness. Under-controllers display a tendency towards a higher rate of antisocial behavior and lower popularity (Asendorpf, 2001, 175).

It is apparent that the flexibility of the resilient prototype should predispose such a person to the often stressful role of a business owner. We therefore expect to see many individuals in our sample – which considerably differs from a sample of the general population due to its exclusive focus on owner-entrepreneurs – to be of this type. In addition, in accordance with our hypotheses above, the resilient prototype is expected to more likely self-select into the DUI mode of innovation. DUI mode learning may be more dependent on personality characteristics than the STI mode as – in the absence of R&D competencies – it requires the absorptive capacity of the owner to access external knowledge as well as his/her coordinating and communicating role in organizing its application internally.

Our analysis points towards a two-cluster solution (see Table 3). C2 – the largest group in our sample (N=925) – clearly represents the resilient prototype, as we find high scores for extraversion, conscientiousness, emotional stability, as well as openness to experience. The other cluster (C1) can be identified as over-controllers. While generally scoring lower in all trait scores than C2, the similarity for the agreeableness score as well as the below-average scores for extraversion and emotional stability speak for an interpretation as the over-controlled type. Moreover, the high overall conscientiousness score (12.059) implies that the under-controlled type rarely exists in our sample, as under-controllers are often particularly low on conscientiousness (see Asendorpf, 2001; Asendorpf and van Aken, 2001). Our results suggest that the under-controlled personality prototype is largely absent from the population of business owners. While this finding is intuitively plausible – antisocial tendencies and lower popularity are inherently problematic in people-centered activities such as entrepreneurship – it also opens up future avenues of research in this regard.

It can be argued that individuals with a high conscientiousness score are more likely to return a survey than those with lower levels of conscientiousness, thus potentially introducing a sample-selection bias. First, if true, this mechanism would introduce a self-selection bias in any survey data whatsoever, including large panel data sets previously employed to study entrepreneurial personality traits. However, to our knowledge, no such bias has been detected by previous research. Second, while it is conceivable that the conscientiousness trait predisposes individuals to complete a survey once started, it is less plausible that it should affect the motivation to fill out a survey in the first place since we did not offer any incentives for doing so. Finally, the high levels of conscientiousness (and the absence of under-controllers) in our survey can be explained by previous empirical research. Based on their empirical analysis, Zhao et al. (2010) state that “more conscientious people are attracted to entrepreneurship” (p.395). Zhao and Seibert (2006) report similar results.⁴

Having obtained the cluster solutions for the modes of innovation and personality prototypes, we investigate the relationships between these variables to examine our hypotheses. We perform a regression analysis in two stages. First, we regress the binary innovation variable against the five personality trait variables (or two personality prototypes), in addition to a number of covariates. We perform a binary probit model with standard errors that are clustered by municipality. Second, we perform multinomial probit regressions to examine the factors that affect self-selection into the four modes of innovation. In this case, our dependent variable is categorical in nature. Companies fall into the base category if they are non-innovative (the variable “Innovation” equals 0). The remaining categories signify our four innovation mode clusters (C1-C4). Table A2 in the appendix provides descriptive statistics on the dependent and control variables.

achieved more distinct groups with respect to the R&D variable. As the varying importance of in-house R&D lies at the heart of the STI/DUI concept, we refrained from non-hierarchical clustering there.

³ Prototypes have been shown to predict several individual longitudinal outcomes, such as social relationships, intellectual ability and temperamental traits (Asendorpf and Denissen, 2006; Asendorpf, 2003).

⁴ Similarly, Rauch and Frese (2006) state that “if overall conscientiousness is used to predict entrepreneurial success, the two underlying contradictory correlations [dutifulness and achievement striving] may lead to an overall small positive correlation” (p.358).

Table 3. Two-cluster solution (personality prototypes)

	Overall mean	C1	C2	Chi2	
		Over-controlled	Resilient		
<i>Cluster solution in terms of the clustering variables</i>					
Extraversion	9.483	8.235	10.598	387.188	***
Agreeableness	8.310	8.264	8.351	0.785	
Conscientiousness	12.059	11.115	12.903	306.993	***
Emotional stability	9.632	8.783	10.390	197.964	***
Openness to experience	9.552	7.436	11.443	939.947	***
<i>Validating the cluster solution</i>					
Innovation ^a		0.632	0.698	8.295	***
Product innovation		0.188	0.243	7.835	***
Process innovation		0.196	0.256	8.860	***
N		826	925		

Notes: The table displays mean values for the Big Five variables, each of which ranges from 1-14 and statistical significance of cluster differences (***)significance level of 1 percent, Kruskal-Wallis test with ties, Pearson's chi-square test). Cluster results are obtained by applying a two-step procedure (hierarchical clustering followed by k-means).

^a i.e. product innovation and/or process innovation and/or innovation-related digitalization measures

4. Results

4.1. Personality characteristics and firm-level innovativeness

Table 4 displays the marginal effects for the first set of probit regressions, in which we regress the binary innovation variable against the owner's personality characteristics and additional controls. All main results are robust to model specification, and unreported marginal effects obtained through logit and OLS regressions are almost identical to those reported here. As can be seen, the Big Five characteristics of extraversion and openness affect the likelihood of innovation positively and significantly across specifications 1 to 3, and the effect sizes are considerable. An increase in extraversion (on a 1-14 scale) increases the likelihood of innovation by 0.7 percentage points (specification 3). In other words, if an individual's extraversion score lies one standard deviation (s.d. = 2.51) above the mean, the innovation likelihood increases by 1.75 percentage points.

Similarly, openness to experiences also positively affects the dependent variable across specifications. We find the same effect size as in the case of extraversion (0.7 percentage points). Consequently, a one-standard-deviation increase on the openness scale (2.8) increases innovativeness by 1.96 percentage points. While the Big Five trait of emotional stability is also positively related to innovation (0.8 percentage points), it is only statistically significant in our full specification (specification 3). A one-standard-deviation increase in the emotional stability scale (2.41) raises innovativeness by 1.9 percentage points. In combination, the three variables exert considerable influence on innovativeness. A moderate increase in all three traits (extraversion, emotional stability, and openness) by one standard deviation would increase the likelihood of innovation by 5.6 percentage points.

These results therefore support Hypothesis 1, suggesting that a more communicative business owner increases the company's absorptive capacity by more intensively interacting with external contacts. He/she will also interact more frequently with employees, thus increasing the internal dissemination and application of new external knowledge. Openness to new experiences heightens the owner's interest for novelty, whether in the form of external knowledge or innovative ideas by his/her employees. One can surmise that the trait of emotional stability increases self-confidence and resiliency in the face of setbacks.

The marginal effects of the covariates are in line with our expectations. We control for trade groups, leaving out main construction as a control group. We see an increased likelihood of innovation in the case of trades for industrial needs (companies that frequently belong to industrial supply chains) and automobile trades, which also holds close ties to automotive manufacturers. By contrast, there is a reduced likelihood of innovation in the case of cleaning services, the smallest sector in our sample. There is a clear effect of firm size on innovation, whereby the likelihood of innovation rises by 0.6 to 1.0 percentage point for each percentage-point increase in the number

of employees. Moreover, a company's innovativeness increases if customers are located outside a purely regional context (state, national or international). We find that the higher the degree of competitive pressure, the higher the likelihood of innovation. This effect may stem from co-location benefits that have been repeatedly highlighted in the literature (Audretsch et al., 1996; Murata et al., 2014), as well as from being driven into finding more nuanced niches product/services in the face of fierce competition. As expected, a number of investment motives are positively related to innovativeness (e.g. increase of revenue, rationalization/lower costs, technological modernization). Finally, companies with academically-trained owners are more likely to innovative, although this effect is not statistically significant.

The variable `W_patents` measures the number of individual patent holders in a 50 km radius around the company. It does not seem to affect the dependent variable. Similarly, '`W_own_branch_comp`' measures the number of companies of the same trade group within a 50 km radius. While the negative impact initially seems perplexing, one must remember that we are dealing with a self-reported innovation measure. The more similar companies that there are, the more that owners are aware of what they are doing, deflating their impression about their own innovative successes. Finally, there is a plausible age effect, whereby one more year reduces the likelihood of innovation by 0.4 percentage points.

Specifications 4 to 6 extend the analysis by replacing the Big Five trait scores with the two personality prototypes, which are the result of our cluster analysis above (see Table 4). We find that the combination of certain traits – notably the resilient type – has a considerable impact on our dependent variable. If the owner falls into the category of the resilient personality type, the likelihood of innovation increases by 5.1 to 7.3 percentage points. The resilient type combines the high scores of extraversion, emotional stability, and openness (as well as conscientiousness), each of which increases innovativeness (see specifications 1 to 3). Hence, there is evidence in support of Hypothesis 2.

Table 4. Marginal effects after Probit (binary dependent variable: 'innovation'^a)

	(1)	(2)	(3)	(4)	(5)	(6)
Extraversion	0.011***	0.011***	0.007*			
Agreeableness	-0.006	-0.001	0.003			
Conscientiousness	-0.008	-0.006	0.001			
Emotional stability	0.005	0.004	0.008*			
Openness	0.011**	0.013***	0.007*			
Over-controlled				-	-	-
Resilient				0.065***	0.073***	0.051***
Log(employees)		0.104***	0.060***		0.104***	0.061***
% Supra regional sales			0.079***			0.078***
Owner with university degree			0.024			0.022
Very low competition			-			-
Low competition			0.053*			0.056*
Medium competition			0.120***			0.120***
High competition			0.124***			0.124***
Increase of revenue			0.101***			0.101***
Rationalization/lower costs			0.129***			0.129***
Technological modernization			0.114***			0.114***
Renewal/Expanding the product range			0.129***			0.131***
Environmental protection			0.039			0.042
Regulatory compliance			0.021			0.020
Main construction		-	-		-	-
Finishing trades		0.016	-0.022		0.015	-0.023
Industrial needs		0.094***	0.068**		0.091***	0.064*
Cleaners		-0.168**	-0.213**		-0.176**	-0.218**
Automobile		0.174***	0.101***		0.167***	0.095**
Foodstuff		0.019	-0.023		0.014	-0.029
Health		0.159***	0.050		0.162***	0.051
Private needs		0.063*	0.021		0.070**	0.022
W_patents			0.000			0.000
W_own_branch_comp			-0.001**			-0.001**
Age			-0.004***			-0.004***
N	1726	1675	1594	1726	1675	1594

Notes: Standard errors are clustered by geographic units; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

^a i.e. product innovation and/or process innovation and/or innovation-related digitalization measures

Table A3 in the appendix displays results for an additional regression, in which we replace the catch-all innovation variable – which combines several types of innovation – with each individual component. It is interesting to see that personality does not seem to be equally related to all innovation types. In particular, we find an effect on process innovations (specifications 3, 4, and 10) and no impact on product innovations. The stronger impact of a small business owner’s personality on process innovation activity may result from the fact that knowledge underlying new or improved business processes tends to incorporate a higher degree of tacitness compared to product innovations, since it tends to be more strongly related to person-embodied know-how and an intimate familiarity with firm-internal processes (Gopalakrishnan et al., 1999). Hence, the hypothesized link between an owner’s personal characteristics and the firm’s absorptive capacity should be particularly relevant in case of process innovation. Put more generally, the stronger impact on process innovation activity may result from the fact that the implementation of new or improved processes is closely interlinked with organizational learning (OECD/Eurostat, 2018). This leads us to the second stage of the regression analysis.

4.2. Modes of innovation and personality characteristics

Having established the empirical relationship between personality characteristics and innovation outcomes, we now proceed to test the impact of a small business owner’s personality on self-selection into specific modes of innovation (notably the DUI mode) to account for the organizational level of absorptive capacity. The multinomial probit coefficients are reported in Table 5, which should be understood in reference to our baseline group in terms of relative probabilities (0 = non-innovative). Specifications 1 to 4 (as well as 5 to 8) list factors that determine the relative likelihood of falling into a particular mode of innovation instead of falling into the category of non-innovative firms. Column (1) displays a positive and significant coefficient for the binary variable ‘resilient’. Thus, an owner of this personality prototype is more likely to self-select into the open DUI group in comparison to falling into the baseline group. Similarly, column 4 (STI/DUI group) also displays a positive and significant coefficient for the variable ‘resilient’. We can therefore conclude that resilient owners can more likely be found in the open DUI group or the STI/DUI group, rather than not being innovative. The stronger effect of an owner’s personality type in case of the open DUI group supports Hypothesis 3.

In specifications 5 to 8, we replace personality prototypes by the Big Five traits. Again, we find evidence of a relationship between personality and self-selection into a specific innovation mode. Emotional stability and openness make it more likely to be found in the open DUI group instead of not being innovative. Extraversion increases the likelihood of being in the closed DUI group (compared to the non-innovative group). We interpret this as an indication that extraversion – as argued above – is not only relevant in case of outward-looking components of absorptive capacity, but also for triggering internal processes of DUI learning. Finally, extraversion, emotional stability, and openness increase the likelihood of being in the STI/DUI group as opposed to being in the baseline group of non-innovative firms.

While the coefficients in Table 5 must always be interpreted in reference to the baseline group, the marginal effects of our multinomial probit coefficients are reported in Table 6. The marginal effects show the impact of a variable on the absolute likelihood of falling into the corresponding group. Columns 1 to 5 show that the resilient owner is 4.2% less likely to be found in the no-innovation group and 3.1% less likely to be found in the low learning group. By contrast, he/she is 4.3% more likely to be found in the open DUI group. Again, this finding supports Hypothesis 3.

In specifications 5 to 9, we again turn to individuals Big Five traits. Again, we find that emotional stability and openness are positively associated with the open DUI mode. A high degree of conscientiousness and less openness make it more likely to be found in the low learning group. Finally, we do not find any association between separate Big Five traits and the likelihood of being in the closed DUI or the STI/DUI group.

Overall, the findings support our hypotheses. A certain combination of personality traits – such as the resilient prototype – makes it more likely to be innovative in general, but it also makes it more likely that the owner self-selects into a specific mode of innovation, particularly in the case of the open DUI group. Hence, the personal characteristics of small business owners indeed play a role in terms of whether or not absorptive capacity can mediate between external knowledge and firm-level innovativeness in less R&D-intensive SMEs.

5. Conclusion

The absorptive capacity of firms is a matter of ongoing debate. Previous studies primarily attribute the existence of absorptive capacities to a firm's prior in-house R&D activity. It is also known that the innovation performance of many smaller firms is strongly based on external knowledge sourcing and external partnerships. However, if SMEs use external knowledge but do not conduct their own R&D activity – which could facilitate the absorption of such knowledge – we are left with a missing link. The present paper addresses the corresponding research gap by focusing on the small business owner and the role of his/her personality characteristics in the development of absorptive capacities.

Our results show that small business owners can be conceptualized as centralized knowledge gatekeepers in the sense of Cohen and Levinthal (1990). They contribute to a firm's absorptive capacity, which mediates between external knowledge sourcing and innovation performance in the case of less R&D-intensive SMEs. By applying the well-known Big Five personality model to the topic of firm-level innovativeness, it becomes clear that absorptive capacity is not only tied to specific personality traits of the owner (like openness or extraversion); instead, the empirical analysis shows that complementarities between different personality characteristics exist in terms of inward- and outward-looking components of absorptive capacity. Accordingly, our paper contributes to the Big Five literature.

Furthermore, we find that the owner's personality is increasingly relevant the more strongly that the firm's innovation activity is based on the DUI mode. In case of innovation activities that emphasize internal as well as external kinds of interactive DUI learning ('open DUI group'), the owner's personality plays a significant role. Under such conditions, the small business owner acts as a knowledge gatekeeper who ensures that his/her individual absorptive capacity is transformed to organizational absorptive capacity by stimulating DUI learning processes within the firm. Especially for innovation activities that are conducted without R&D, it is therefore crucial that the owner is not only able to identify and understand relevant external knowledge but also to create an internal learning culture so that the corresponding knowledge inputs are successfully communicated and transmitted among his/her employees. Through its focus on the owner's personality, the present paper has thus provided a new perspective on DUI mode learning and thus contributes to the growing literature on innovation modes. Our paper also contributes to the more general literature on non-R&D innovation by showing how innovating SMEs can effectively compensate for a lack of in-house R&D capacity.

One potential limitation of our paper is that despite our efforts to create a random data set (see Section 3.1) it suffers from selection bias. In particular, one may wonder why the overall conscientiousness score of our survey participants appears to be quite high on average (12.06; see Table 3). An obvious explanation could be that owners who are more conscientious are more likely to fill out and send back a questionnaire. If this is true, less diligent and less organized persons (so-called 'under-controllers') may be underrepresented in our data set. While we cannot fully rule out this point (see Section 3.2), we argue that the specific sub-group of owner-entrepreneurs are likely to have a higher conscientiousness score than other population groups to keep their business running. In fact, the results of Zhao and Seibert (2006) as well as Zhao et al. (2010) point in this direction. However, further empirical research is required to validate this argument.

There are some management implications of our results. Studies on internal barriers to innovation usually focus on employee-related obstacles such as resistance against change or organizational problems, while the person of the owner-entrepreneur tends to be neglected. A small business owner must realize that firm-level innovativeness does not depend on him/her alone; rather, a transformation into organizational absorptive capacity is required to increase the likelihood to innovate. For this purpose, a learning culture must be created that builds on attributes such as employee autonomy, free scope for development or delegation of decision-making powers. Overly self-assured owner-entrepreneurs who think they alone can spur innovation may therefore rethink their role to realize the full potential of their company in terms of innovation.

With respect to policy implications, our results provide a hint that policy-makers aiming to support SME innovation should pay attention to the psychological basis of a firm's absorptive capacity. Personality traits are relatively constant and stable over time. Nevertheless, entrepreneurship education programs targeting potential founders may offer tailor-made courses that take into account specific personality characteristics, raising awareness of their own strengths (which can be further developed) and weaknesses (which can be compensated). Moreover, while we cannot evaluate the cost-benefit ratio of such support measures, our results may provide policy-makers with a justification for technology transfer activities, since those small business owners who are receptive and willing to learn may still require some impetus from outside to identify relevant knowledge sources in their external environment. Given the existing framework of innovation support structures, the organizational component of absorptive capacity may also attract the attention of policy-makers. Support programs that target innovating SMEs often pay strong attention to a smaller firm's access to financial resources. Our results imply that an alternative approach could support smaller firms in implementing DUI mode learning (e.g. by guiding to use human resource management tools or teamwork practices) to develop organizational absorptive capacity.

Future research can deepen our understanding of the relationship between the personality characteristics of small business owners and the concept of absorptive capacity. For example, the examination of personality traits that are more specific and changeable than the broad and abstract Big Five traits (such as risk-taking, self-efficacy, need for achievement or internal locus of control; see e.g. Obschonka and Stuetzer 2017) may provide additional insights into the psychological basis of an owner's absorptive capacity. A closely-related avenue for future research refers to the self-selection

into specific modes of innovation. Based on our data, an interpretation of the ‘low learning group’ was only possible to a limited extent. Our regression results of Table 6 suggests that companies with owners who are less open and more conscientious are more likely to fall into this group, although these companies report being innovative. Further research on this issue is necessary to better understand the learning mechanisms in this group of firms. Finally, due to our focus on the development of absorptive capacities in less R&D-intensive SMEs, our focus was on the DUI mode of learning and innovation. However, our empirical results suggest that there are also some links between an owner’s personality traits and self-selection in the STI mode. Further delving into this topic may be another fruitful avenue for future research.

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Appendix A

Table A1. Company size (sample and population)

	Sample	Overall population ^a
Number of employees	10.2	8.0
Net annual revenue (in Euro)	1.164.516,5	707.153
<i>Size classes</i>		
Fewer than 5 employees	46.19%	64.7%
5-9 employees	23.35%	19.0%
10-19 employees	15.00%	9.3%
20-49 employees	9.13%	5,0%
More than 50 employees	6.33%	2.0%

^a Federal Statistical Office of Germany (2018)

Table A2. Descriptive statistics

Variable name	Mean	SD	Variable name	Mean	SD
<i>Binary variables on innovation</i>			<i>Investment motives</i>		
Innovation ^a	0.639	0.481	Increase of revenue	0.195	0.396
<i>Modes of innovation</i>			Rationalization/lower costs	0.211	0.408
Non-innovative	0.361	0.481	Technological modernization	0.351	0.477
Open DUI	0.137	0.344	Renewal/expanding the product range	0.109	0.312
Closed DUI	0.148	0.355	Environmental protection	0.084	0.277
Low learning	0.106	0.308	Regulatory compliance	0.123	0.328
STI/DUI	0.248	0.432			
<i>Personality types</i>			<i>Trade groups</i>		
Over-controlled	0.483	0.500	Main construction	0.252	0.252
Resilient	0.517	0.500	Finishing trades	0.151	0.358
<i>Personality traits</i>			Industrial needs	0.154	0.361
Extraversion	9.422	2.510	Cleaners	0.025	0.156
Agreeableness	8.285	2.348	Automobile	0.144	0.352
Conscientiousness	11.980	2.178	Foodstuff	0.105	0.306
Emotional stability	9.630	2.409	Health	0.056	0.230
Openness	9.517	2.802	Private needs	0.113	0.317
Employees	10.096	19.288	W_patents ^b	353.977	271.109
% Supra regional sales	0.583	0.493	W_own_branch_comp ^c	102.547	54.423
Owner with university degree	0.220	0.414	Age	54.035	9.234
<i>Competitive pressure</i>					
Very low	0.218	0.218			
Low	0.244	0.430			
Medium	0.374	0.484			
High	0.164	0.370			
N	1434				

Note: Table A2 summarizes all variables based on a sample without missing values for any of these variables.

^a i.e. product innovation and/or process innovation and/or innovation-related digitalization measures.

^b W_patents measures the number of patents which have been applied for within a 50km radius around the firm in the last two years.

^c W_own_branch_comp measures the number of companies of the same trade group within a 50km radius around each firm.

