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# A hidden source of innovation? Revisiting the impact of initial vocational training on technological innovation

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**Abstract**

While an increasing number of studies postulate that vocational education and training (VET) activities have a positive impact on the innovative capacity of training companies, empirical evidence on the topic remains contradictory. This study exploits establishment data from a representative survey of German companies to estimate the relationship between firms' participation in initial VET and their innovation outcomes. Our results show that the direct effects of initial VET on technological innovation in small and medium-sized enterprises (SMEs) are on average quite weak. If at all, a training firm's initial VET activities are associated with production innovation activities and not with process innovation. Larger effects can only be observed in case of microenterprises with fewer than ten employees. In these firms, initial VET is associated with a higher probability of (local) new-to-market product innovation if it is accompanied by changes in organizational processes that support individual learning and knowledge creation. We conclude from this finding that the knowledge diffusion function of the VET system primarily holds relevance for the smallest of the training companies and that initial VET is only positively related to technological innovation when it goes along with organizational learning in the training company.

JEL: I20, J24, O31
Keywords: Innovation; Vocational education and training (VET); Knowledge diffusion; Organizational learning; SMEs

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## 1. Introduction

In recent years, the question of the role that vocational education and training (VET) potentially plays for innovation has gained increasing attention in scholarly research (e.g. Barabasch and Keller 2020; Hodge and Smith 2019; Lund and Karlsen 2020; Porto Gómez, Zabala-Iturriagagoitia, and Aguirre Larrakoetxea 2018; Rodríguez-Soler and Icart 2018; Rupietta and Backes-Gellner 2019; Rupietta, Meuer, and Backes-Gellner 2021). Regarding the role of VET institutions in this context, for example, it has been empirically shown that they provide an important contribution to the functioning of regional innovation systems (Lund and Karlsen 2020; Porto Gómez, Zabala-Iturriagagoitia, and Aguirre Larrakoetxea 2018; Rodríguez-Soler and Icart 2018).

It would be expected that the empirical evidence at the company level is analogous to this, although surprisingly this is not the case. The studies conducted by Hodge and Smith (2019) and Rupietta and Backes-Gellner (2019) provide different results regarding the direct influence of initial VET activities on technological innovation activities in training firms (i.e. in terms of the contribution of VET students to a firm's propensity to introduce new or significantly improved products, services or processes). While the first study – based on qualitative interviews from Australia – does not provide clear evidence that VET students contribute directly to a firm's technological innovativeness during their time of work placement, the second study – based on Swiss firm data – provides quantitative evidence that apprenticeship training has a positive impact on technological innovation under the conditions of dual VET systems.

According to Rupietta and Backes-Gellner (2019), the effect of initial VET on technological innovation outcomes follows an inverted u-shape with increasing firm size, i.e. the impact on innovation seems to be stronger for smaller enterprises, and tends to apply to product rather than process innovations. However, since small and medium-sized enterprises (SMEs) are a quite heterogeneous entity in terms of innovation (Thomä and Bizer 2013; de Jong and Marsili 2006), it remains unclear exactly to which subgroup(s) of SMEs this effect applies. This is relevant insofar as it is known from the empirical literature on the motives of companies to participate in apprenticeship that the productivity of VET students is on average higher the smaller a training company is (see e.g. Mohrenweiser and Backes-Gellner 2010; Muehlemann and Wolter 2014; Mühlemann 2016) – which, conversely, could indicate that there may be a positive relationship between initial VET and innovation in very small firms in particular. Moreover, Rupietta and Backes-Gellner’s non-significant result on process innovation outcomes appears surprising given that – compared to product innovation – the knowledge associated with improvements in business processes often contains a relatively high degree of tacitness (Gopalakrishnan, Bierly, and Kessler 1999), which should be related with a stronger importance of VET-based learning and skills in this context (on this issue see Thomä 2017). Moreover, the Swiss study of Rupietta and Backes-Gellner (2019) does not distinguish between different degrees of innovative novelty. However, especially regarding incremental innovation, a potential contribution by VET students could be expected (Toner 2010).

By contrast, the qualitative results of Hodge and Smith (2019) imply that a VET student’s contribution to firm-level innovation should not be overestimated, at least under conditions of full-time, school-based vocational training systems with company practice periods being constrained to temporarily limited work placements. The following pointed question by the authors illustrates this finding: ‘If VET students, like any students, are novices in an occupational area, why would we expect to find they contribute to innovation?’ (p. 16). Hodge and Smith (2019) nevertheless argue that VET activities may still contribute to a firm’s technological innovativeness in two relevant ways: through knowledge diffusion and via organizational learning. With regard to the former, they expect VET students to be potential mediators of knowledge diffusion stemming from vocational education institutions. This may explain the finding of Rupietta and Backes-Gellner (2019) that the effects on innovation are stronger in smaller firms, given that – mostly at the level of regional innovation systems – SMEs are probably profiting most from the VET system's important function in terms of knowledge diffusion (Lund and Karlsen 2020; Porto Gómez, Zabala-Iturriagagoitia, and Aguirre Larrakoetxea 2018; Rodríguez-Soler and Icart 2018). Regarding the second driver, according to Hodge and Smith (2019), initial VET can lead to improved day-to-day organizational practices in training firms (including changes in workplace organization, new organizational methods etc.) – either through a direct role of VET students in introducing such organizational changes or through the more general changes in organizational learning processes that follow a company’s decision to participate in initial VET. Such organizational innovations have been shown to significantly improve the technological innovation performance of non-R&D-intensive SMEs (Rammer, Czarnitzki, and Spielkamp 2009; Hervas-Oliver et al. 2015) – which raises the question of how initial VET, organizational changes and technological innovation are related in the case of (smaller-sized) training firms (Rupietta, Meuer, and Backes-Gellner 2021).

Hence, the question remains whether conducting initial VET actually fosters technological innovativeness at the company level. Against this background, our paper aims to contribute to the literature in two related ways. First, compared to the Australian study of Hodge and Smith (2019), our empirical analysis uses a broad data set from Germany, a country where the dual system of VET forms an integral part of the national innovation system (Thomä 2017). Due to the duality of vocational training (i.e. the combination of long periods of practical learning in companies and theoretical learning at vocational schools), German VET students may contribute to firm-level innovation to a stronger degree compared to VET students in countries where initial VET takes place mainly in full-time vocational schools with limited practical periods during the time of training. Moreover, we aim to provide empirical evidence for the relationship between initial VET and technological innovation by placing a special emphasis on the role of knowledge diffusion and organizational learning, and hence supplement the study of Hodge and Smith (2019).

Second, regarding the quantitative Swiss study of Rupietta and Backes-Gellner (2019), we add to the literature by distinguishing between different categories of SMEs to shed further light on the role of firm size in the present context. Moreover, by using a wider set of control variables and developing a comprehensive theoretical foundation for explaining the potential impact of initial VET on smaller firms' technological innovation activities we complement Rupietta and Backes-Gellner (2019). In a broader sense, this is also a contribution to the empirical literature that quantitatively addresses the question of whether training companies benefit from their investments in initial VET already during the apprenticeship period in terms of the VET student's productivity (e.g. Zwick 2007; Mohrenweiser and Backes-Gellner 2010; Muehlemann and Wolter 2014; Lerman 2019) – since we assume that an employee's productivity and his/her contribution to firm-level innovation are intertwined.

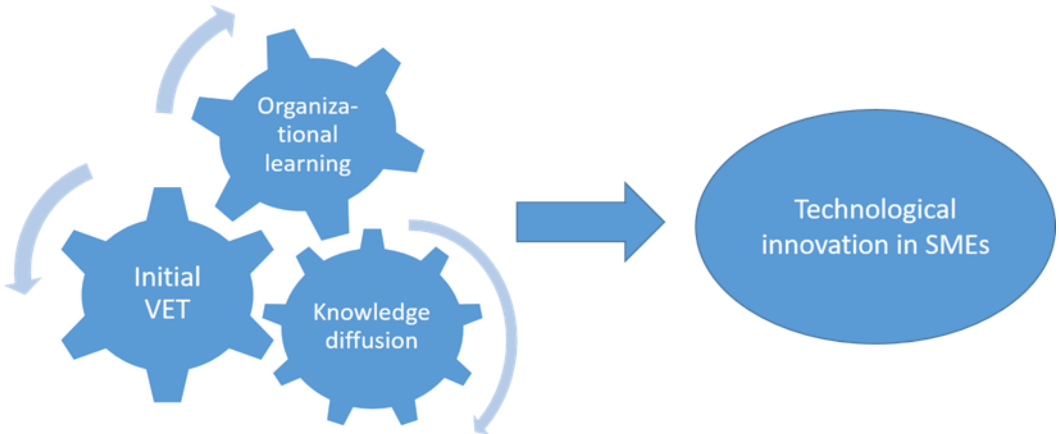
The remainder of the paper is structured as follows. In the next section, we review and synthesize a number of theoretical arguments from the literature on how initial VET activities may contribute to knowledge diffusion, organizational learning and innovation at the company level. In the next sections, we introduce the dataset, discuss our estimation approach and present our main empirical results on the relationship between initial VET and technological innovation at the company level. Finally, the paper concludes with implications for policy and further research.

## 2. Innovation in the majority of German SMEs: Learning beyond formal R&D

### *2.1. Overview on the conceptual framework*

In line with Hodge and Smith (2019) and Rupietta and Backes-Gellner (2019), we assume that knowledge diffusion and organizational learning are important determinants of innovation for many SMEs in Germany (Figure 1).[1] Our main argument at this point is that initial VET activities at the company level are closely involved in corresponding learning processes and knowledge dynamics, leading to a mutual reinforcing relationship between these three elements and SME innovation, which tends to be overlooked by innovation scholars and policy-makers alike (Porto Gómez, Zabala-Iturriagagoitia, and Aguirre Larrakoetxea 2018). Our conceptual framework is therefore based on organizational learning and knowledge diffusion as two main drivers through which initial VET can foster technological innovation in SMEs.

Figure 1. Initial VET as a driving factor for innovation in SMEs




The first refers to the key importance that the dual VET system has for the German innovation system in terms of knowledge diffusion, especially at the regional level (Thomä 2017). Effective diffusion of new technologies throughout the economy is an essential precondition for SMEs' innovation success hence constituting a crucial starting point for

[1] At the same time, we fully acknowledge that the relationship between training activities and a firm's propensity to innovate is complex, as causality may run in opposite directions (Bauernschuster, Falck, and Heblich 2009). Innovation activities could increase the need to train employees in new technologies or processes (i.e. innovation drives training), while on the other hand a company's training activities may have a positive impact on its innovation capacity (i.e. training drives innovation). This could also apply to the specific case of initial VET. Since in the present paper we are interested in its effect on technological innovation, our empirical approach aims at reducing the likelihood of reverse causality (see Section 4).

policy measures and support. By means of knowledge diffusion, SMEs frequently receive the necessary stimulus for developing innovations. Thus, increasing the absorptive capacity of smaller firms concerning external knowledge, focusing on a broad set of institutions that affect learning and innovation (including VET institutions such as vocational schools or vocational training centres), integrating SMEs in regional innovation systems and upgrading workforce skills in SMEs to facilitate participation in innovation are vital (Rammer, Czarnitzki, and Spielkamp 2009; OECD 2010; Hervás-Oliver et al. 2021; Hewitt-Dundas 2006; Thomä 2017). The second driver relates to the fact that informal ways of learning by doing, using and interacting (DUI) are particularly strong in the case of SME innovation, not least in the 'German Mittelstand' (Pahnke and Welter 2019; Kirner, Kinkel, and Jaeger 2009; Kirner, Som, and Jäger 2015; Thomä 2017; Alhusen et al. 2021). In Germany, the VET trained workforce plays a key role for DUI-based innovation activities in non-R&D-intensive firms and industries (Thomä 2017; Thomä and Zimmermann 2020). Moreover, DUI-based technological innovation usually requires deep organizational learning in order to be successfully implemented at the company level. According to Rammer et al. (2009), this is especially true for the large number of innovating SMEs in Germany that compensate for their lack of formal research and development (R&D) by placing special emphasis on management practices to foster interactive learning within the firm and external knowledge inflows.

### *2.2. VET and knowledge diffusion*

Toner (2010) argues that the VET system plays a critical role in knowledge diffusion, particularly regarding innovation in SMEs, which are not at the frontier of technological development. The author stresses the importance of vocational education institutions such as vocational schools, vocational colleges or vocational training centres as being highly responsive to the particular needs of local industries, offering customized training programs, serving as technology intermediaries between equipment or software producers and local businesses, and informing their students about new technologies, which increases the absorption capacity of a training company's workforce in terms of both practical skills and knowledge regarding production processes.

The studies of Porto Gómez, Zabala-Iturriagagoitia, and Aguirre Larrakoetxea (2018), Rodríguez-Soler and Icart (2018) and Lund and Karlsen (2020) analyse empirically the role of vocational education institutions for the functioning of regional innovation systems with some indications of effects at the company level. For example, the former conclude that for many industrial SMEs in Spain (Basque Country and Catalonia) VET institutions represent the main source of external technological knowledge for the training companies and can therefore play a central role in technological innovation at the company level. Moreover, it is shown that this is especially the case for DUI-based innovation activities in training companies, which are triggered by the demand-based and problem-solving-oriented training opportunities provided by VET institutions and 'the type of skills and expertise held by their staff and the long-lasting [trust-based] relationships between these and local firms' (Porto Gómez, Zabala-Iturriagagoitia, and Aguirre Larrakoetxea 2018, p. 217). For the Spanish regions of Catalonia and Aragon, Rodríguez-Soler and Icart (2018) find that geographical proximity to VET institutions is crucial for external knowledge sourcing in training companies. In this way, VET institutions can be a driving force of knowledge transfer to the company level. VET institutions are described as 'a key node' (p. 13) in the knowledge network of DUI-oriented SMEs.

Lund and Karlsen (2020) confirm the results of the Spanish studies with a focus on two Norwegian manufacturing regions, concluding that VET institutions are important sources of external knowledge for local SMEs. According to their results, vocational colleges promote the competitiveness of manufacturing firms by developing programs for education tailored to regional industries that consider current technological trends and state-of-the-art technologies and new materials, which shows how VET institutions are driving the dissemination of new technologies in training companies. According to the authors of this study, these findings provide a better understanding of the DUI mode of innovation in training companies.

For the case of Switzerland, Rupietta and Backes-Gellner (2019) establish that the involvement of highly innovative companies in institutionalized curricula-updating processes promote technology and knowledge diffusion among training-companies enhancing companies' innovation capacities. Following their argument, training firms constantly face new technologies of the industrial leaders. By learning about these technologies, training firms develop in comparison to non-training companies competitive advantages. In this process, SMEs are assumed to benefit from absorbing and adapting new knowledge and technologies whereas large companies are attributed to contribute innovative input to curricula updating.

### *2.3. VET and organizational learning*

Technological innovation activities at the company level can be based on different learning sources (Santamaría, Nieto, and Barge-Gil 2009). According to Jensen et al. (2007), innovating firms can be roughly distinguished according to the degree to which they have integrated formal processes of learning related to R&D and the extent to which they use informal ways of DUI learning. In this context, the innovation activity of smaller firms is often described as minimally or not at all R&D-intensive and being strongly rooted in the DUI mode (Baldwin and Gellatly 2003; de Jong and Marsili 2006; Tödtling and Kaufmann 2002; Hirsch-Kreinsen 2015). Important elements of DUI-based innovation activities in SMEs are an emphasis on experience-based learning from informal problem-solving communication, interactive learning with customers or suppliers, the overall importance of locally embedded tacit knowledge and the fostering of organizational learning within the firm by building up (informal) interaction structures (Thomä and Zimmermann 2020).

According to Toner (2010), processes of learning by doing and using are at the core of VET activities in training companies. Hence, it is only logical to expect a close link between a company’s participation in the VET system and its integration of the DUI mode of learning and innovation (Thomä 2017). Within the DUI mode, practical problem-solving skills developed in production processes hold key importance for innovation activities at the firm level (Jensen et al. 2007). The VET system provides employees with corresponding skills and underpinning knowledge and hence raises the workforce's absorptive capacities (Toner 2010). In this way, knowledge flows within and between firms are facilitated (Proeger 2020; Rupietta and Backes-Gellner 2019) and VET students are enabled to potentially act as technology gatekeepers (Rupietta, Meuer, and Backes-Gellner 2021). As a result, some studies in the DUI literature stress the importance of VET as an important element of innovation processes in SMEs. For example, Thomä (2017) argues that VET plays a key role in product and process innovation activities in non-R&D-intensive firms and industries. Similarly, the empirical results of Thomä and Zimmermann (2020) imply that VET is a key driver of innovation in SMEs that are engaged in customer-oriented DUI innovation. To offer another example, the study of Alhusen and Bennat (2021) shows that ’learning-by-training’ through VET activities is mainly employed by SMEs that rely on the DUI mode in some way or another.

Furthermore, the VET literature argues that apprenticeship activities can positively influence the organizational learning processes of training companies in two interrelated ways (Barabasch and Keller 2020; Hodge and Smith 2019; Rupietta, Meuer, and Backes-Gellner 2021): Either through the direct contribution of VET students to new day-to-day organizational practices implemented in their training company, or more indirectly through the implementation of a more distinctive learning culture developed in training companies as a result of the decision to participate in the VET system. Such organizational learning processes, in turn, are an important determinant of the DUI mode of innovation (Thomä 2017; Parrilli, Balavac, and Radicic 2020; Parrilli and Radicic 2021). Indeed, organizational learning and creating a corresponding business culture are considered by Asheim and Parrilli (2012) to be the micro-foundation of DUI-based technological innovation, which is why Thomä (2017) considers organizational innovation to foster individual learning and knowledge creation (e.g. through promoting teamwork among employees, delegating decision-making powers, restructuring customer relationships, developing a general culture of open communication etc.) as a necessary prerequisite for the successful integration of the DUI mode at the level of the firm. This may explain the findings of Rammer et al. (2009) and Hervas-Oliver et al. (2015) according to which organizational learning positively affects the technological innovation performance of non-R&D-intensive SMEs. To sum up, it can be expected that initial VET activities exert a positive impact on DUI-based technological innovation in SMEs if they are accompanied by vital processes of organizational learning.

## 3. Data

The following empirical analysis is based on balanced panel data from the IAB EP dataset, an employer survey from the German Federal Employment Agency. The Establishment File of the Federal Employment Agency, which contains all German business units with at least one employee covered by social security, constitutes the sampling frame of the IAB EP. It thus considers all firms in Germany, which conduct initial VET, as long as their apprentices are not exempt from social security contributions. Further information on the dataset and the survey design is provided by Ellguth, Kohaut, and Möller (2014).

Our analysis focuses on the panel waves for 2009-2019, which are accessed via a remote data execution system. Information on 45,013 SMEs is used for the present analysis. For this purpose, the SME definition applied by the European Union (maximum 249 employees) has been applied. In our sample, 38.5% firms report technological innovation outcomes and 43.5% conduct initial VET activities. 44.4% of the companies have fewer than 10 employees, 35.5% between 10 and 49, and 20.6% between 49 and 249 employees (on the descriptive statistics, see Table A 1 in the Appendix). The main variables of interest are indicators for technological innovation, organizational changes and initial VET. By differentiating between general, product and process innovation we follow Rupietta and Backes-Gellner (2019). Additionally, we distinguish between new-to-market, new-to-firm and incremental product innovation. The survey questions on technological innovation are in full compliance with the Oslo Manual measurement guidelines

(OECD/Eurostat 2018).[2] Information on organizational changes[3] is included in the IAB EP dataset at two-year intervals (i.e. the survey years 2010, 2012, 2014, 2015, 2017, and 2019). Since the corresponding survey questions refer to organizational changes conducted within the firm in the last two years, we have replaced missing values in years without information on organizational changes with values from the following year. Finally, the binary variable ‘initial VET’ refers to information from the IAB EP survey on whether a company currently employs VET students (i.e. apprentices) or not.

The dataset allows for the inclusion of a comprehensive set of control variables, e.g. regarding the presence of in-house R&D (for which Rupietta and Backes-Gellner 2019 could not control). In the case of R&D activities, the survey respondents were only asked about this in every second panel wave. However, they were not asked about a specific year, but about the R&D-engagement of company in general. Therefore, and due to the relative persistence of R&D activities in SMEs over time (Máñez et al. 2015), we assume a presence of R&D activities at time t if R&D was carried out in t-1 and t+1, and no R&D activities if no corresponding activities were reported in one or both of these periods.

Descriptive statistics for all dependent and independent variables can be found in the appendix, where a distinction is also made between training and non-training companies (Table A1). Table A2 presents descriptive statistics separately by firm size categories. The correlations between the independent and control variables can be found in Table A3.

## 4. Estimation Strategy

We conduct our analysis using standard ordinary least square estimators with random effects. Since our dependent variables are binary indicators, we employ linear probability models (LPMs). For consistency, we follow Rupietta and Backes-Gellner (2019) and rely on LPM – which is justified as comparable results can be expected from linear and non-linear models (Angrist and Pischke 2008). Due to the binary character of our explanatory variable on initial VET and its relative persistence over time, we opt for random effects models, as fixed effect estimation would cause information loss with respect to companies that continuously train apprentices (Wooldridge 2013). However, we later also resort to fixed effects models to check the robustness of our results.

Our estimation model is thus given by:

$$INNO_{jt} = \gamma_0 + \gamma_1 VET_{jt}\#\#ORGA_{jt} + \sum_{k=1}^{K} \gamma_k x_{kjt} + \alpha_j + e_{jt}\ , \qquad (1)$$

where INNO constitutes the indicator on technological innovation (1 for innovating companies), VET equals 1 if the firm is currently conducting initial VET activities (1 for companies that employ apprentices), ORGA indicates organizational learning that results from changes in a firm’s organizational practices (equals 1 for companies with organizational changes), k denotes the number of control variables, j denotes the number of companies and e is the error term.

In our set of controls, first we include information on workforce qualification based on the share of qualified employees and the share of employees with an academic qualification. Second, we measure competition by analyzing the responses to a question on the competitive pressure in the firm’s market environment (1 for medium or substantial pressure). Third, as a control variable for demand changes, we employ an indicator on the expected business volume (1 if a company expects increasing business volume in the next year). As Rupietta and Backes-Gellner (2019) we control for economic sector, firm size, shortage of skilled workers, foreign ownership and regional dummies. Furthermore, we additionally include controls for continuing training and in-house R&D, as a positive impact on innovation activities can be expected through knowledge creation and improved knowledge flow (Bauernschuster, Falck, and Heblich 2009; Fagerberg, Srholec, and Verspagen 2010).

In addition, we take into account information on the technical status of equipment and investment activity, the former enabling a firm to transform resources into innovations based on its technological endowment. Investment increases this

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[2] The questions asked in the IAB survey 2017 were: ‘In the last business year of 2016, did your establishment improve or further develop a product or service which had previously been part of your portfolio?’ (*incremental product innovation*); ‘In the last business year of 2016, did your establishment start to offer a product/service that had been available on the market before?’ (*new-to-the-firm product innovation*); ‘Have you started to offer a completely new product or service in the last business year of 2016 for which a new market had to be created?’ (*new-to-market product innovation*); ‘Did you develop or implement procedures in the last business year of 2016 which have noticeably improved production processes or services?’ (*process innovation*).

[3] The questions on organisational changes were as follows: ‘Has one of the following changes taken place within your establishment/office in the last two years?: Restructuring of procurement and distribution channels and/or of customer relations; Restructuring of departments or areas of activities; Downward shifting of responsibilities and decisions; Introduction of team work/ working groups with their own responsibilities; Introduction of units/departments carrying out their own cost and result calculations; Improvement of quality management’

endowment and the associated capabilities (Barney 1991; Heidenreich 2009). Our estimation strategy includes both indicators as control variables related to the IAB-EP survey questions on a firms' investment activity (1 for investments, 0 otherwise) and on the technical state of a firm's equipment (1 'state of the art' – 4 'out of date').

Finally, we also include an indicator for export activities, as these positively affect innovation at the firm level (Peters and Rammer 2013). We conduct the analysis for our entire sample of SMEs as well as differentiated by firm size in three categories to investigate the correlation between initial VET and technological innovation for different subgroups of SMEs (fewer than ten, 10 to 49 and between 49 and 249 employees).

## 5. Results

We observe significant associations for initial VET and general innovation (+3.0 %) and new-to-firm product innovation (+1.6 %). Given the corresponding baseline probabilities (i.e. the mean Y-outcomes, see Table 1), both effect sizes must be considered very weak. Hence, similar to Hodge and Smith (2019), our results suggest that the direct effect of initial VET to technological innovation in SMEs is rather small on average and should not be overestimated. For organizational changes, the correlation is significant for all innovation types in almost all firm size categories (Table 1), underlining the link between organizational learning and SME innovation discussed above.

Turning to the interaction between initial VET and organizational changes, we observe a significant association (+4.1%) with new-to-market product innovations in firms with fewer than 10 employees. Hence, in very small firms, initial VET is related to the introduction of new-to-market product innovation if, at the same time, accompanying changes in the training firm's organizational processes support individual learning and knowledge creation. Given the baseline probability of 3 percent in this case (Table 1), the corresponding correlation must be deemed strong.[4] This result is in line with our conceptual framework in Section 2. On the one hand, it shows that initial VET can only be related positively with technological innovation in smaller firms if it is accompanied by organizational learning processes at the company level. Indeed, a number of authors argue that initial VET in countries with a dual VET system, such as Germany or Switzerland, is often associated with a distinct learning and training culture in training firms (Thomas Deissinger 2012; Harris and Deissinger 2003; Pilz 2008; Thomas; Deissinger 2015; Wiemann and Pilz 2020). And from the literature on innovation modes, it is known that DUI mode learning can also drive the generation of more radical technological innovation when it is accompanied by organizational innovation (Apanasovich 2016). On the other hand, we conclude from this finding that the knowledge diffusion function of the VET system is particularly relevant for the smallest of the training companies. This is because a radical innovation performance (compared to incremental technological innovation) relies more heavily on the absorptive capacity of firms in terms of external knowledge acquisition (Forés and Camisón 2016). The knowledge diffusion processes necessary for this seem to take place above all when training companies succeed in generating product innovations on the basis of organizational learning that have a high degree of novelty, at least in their local/regional market environment.

It is interesting that the interaction effect is negative for the entire sample - although the effect size is again very small compared to the base probability (Table 1). The differentiation by innovation type suggests that this is mainly due to the case of incremental product innovations. There, the interaction effect is also significant and negative, probably reflecting the fact that incremental innovation activity means continuous learning along well-established paths - and it is precisely here that organizational changes often have a very disruptive effect (Bourke and Roper 2017).

As a robustness check, we run the regression analysis again using fixed effects models (see Table A4 in the appendix). We also obtain a significant association for the interaction for new-to-market innovations in microenterprises with fewer than 10 employees (+4.6 %), while the main correlation for organizational changes is not significant in this case. The latter can be explained econometrically, as fixed effects estimations do not consider variables that are constant over time (Wooldridge 2013) and thus tend to underestimate the relationship between continuous organizational learning and innovation (Ganter and Hecker 2013).

Consistent with previous research (Hall and Jaffe 2018; Heidenreich 2009), we observe a very strong relationship between R&D and all output measures of innovation. Companies that report formal R&D activities are 8.9% to 26.3% more likely to report innovation outputs (depending on the type of innovation and the size of the firm). Similarly, firms that invest in new technologies and use advanced technological equipment are more likely to innovate, a finding that is consistent with previous studies (Barney 1991; Smith 2005). Furthermore, we find positive associations for continuing training, which is also known from the literature (Bauernschuster et al., 2009; Peters and Rammer, 2013). However, this effect is limited to companies with fewer than 50 employees.

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[4] At this point it should be noted that, especially in the case of small firms, new-to-market product innovations 'do not necessarily need to be world firsts as innovations, but may gain their innovative character from market boundaries such as a regional business focus or a concentration on specific customer groups.' (Thomä and Bizer 2013, p. 38).

Table 1. Regression results (random effects)

| | Linear probability models | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | General innovation | | | | New-to-market product innovation | | | | New-to-firm product innovation | | | | Incremental product innovation | | | | Process innovation | | | |
| | I | II | III | IV | I | II | III | IV | I | II | III | IV | I | II | III | IV | I | II | III | IV |
| Initial VET | 0.030*** | 0.013 | 0.020 | 0.065 | 0.001 | -0.004 | 0.003 | -0.022 | 0.016** | 0.006 | 0.009 | 0.048* | 0.014 | 0.007 | 0.009 | 0.056 | 0.006 | 0.002 | 0.010 | -0.007 |
| Organizational changes | 0.142*** | 0.151*** | 0.135*** | 0.134*** | 0.027*** | 0.021*** | 0.035*** | 0.027 | 0.083*** | 0.094*** | 0.062*** | 0.108*** | 0.112*** | 0.111*** | 0.117*** | 0.120*** | 0.071*** | 0.057*** | 0.088*** | 0.078** |
| VET#ORGA | -0.042*** | -0.012 | -0.031 | -0.061 | 0.015 | 0.041** | -0.004 | 0.021 | -0.019 | 0.009 | -0.008 | -0.052 | -0.024* | -0.003 | -0.026 | -0.051 | 0.005 | 0.028 | -0.019 | 0.010 |
| **Controls** | | | | | | | | | | | | | | | | | | | | |
| Company size | 0.000*** | 0.002 | 0.001* | 0.000 | 0.000 | -0.002** | 0.001** | -0.000 | 0.000 | 0.001 | 0.000 | -0.000 | 0.000*** | 0.004 | 0.001 | 0.000 | 0.000*** | 0.003 | 0.000 | 0.000* |
| Share qualified workers | 0.060*** | 0.043* | 0.076** | 0.034 | 0.010 | 0.004 | -0.002 | 0.055* | 0.024* | 0.030 | 0.006 | -0.010 | 0.049*** | 0.020 | 0.084*** | 0.077 | 0.019* | 0.019 | 0.025 | 0.002 |
| Share of university graduates | 0.176*** | 0.100** | 0.196*** | 0.294*** | 0.055** | -0.022 | 0.080* | 0.116 | 0.047 | -0.010 | 0.059 | 0.112 | 0.145*** | 0.102** | 0.158** | 0.249** | 0.116*** | 0.095*** | 0.130** | 0.070 |
| Shortage of skilled workers | 0.010 | -0.003 | 0.016 | 0.016 | -0.002 | 0.013* | -0.007 | -0.003 | 0.013* | 0.012 | 0.014 | 0.017 | -0.002 | -0.012 | 0.003 | -0.003 | 0.019*** | 0.013 | 0.012 | 0.038** |
| Continuing training | 0.061*** | 0.074*** | 0.051*** | -0.006 | 0.011*** | 0.007* | 0.015** | 0.001 | 0.028*** | 0.043*** | 0.007 | 0.020 | 0.055*** | 0.062*** | 0.054*** | 0.005 | 0.023*** | 0.024*** | 0.026*** | 0.014 |
| R&D activities | 0.189*** | 0.235*** | 0.188*** | 0.166*** | 0.118*** | 0.134*** | 0.136*** | 0.088*** | 0.108*** | 0.145*** | 0.103*** | 0.094*** | 0.205*** | 0.263*** | 0.213*** | 0.165*** | 0.126*** | 0.162*** | 0.109*** | 0.136*** |
| Investment activities | 0.063*** | 0.065*** | 0.047*** | 0.086*** | 0.011*** | 0.014*** | 0.003 | 0.015 | 0.036*** | 0.036*** | 0.033*** | 0.043** | 0.065*** | 0.059*** | 0.062*** | 0.096*** | 0.033*** | 0.033*** | 0.031*** | 0.035** |
| Technical equipment | 0.040*** | 0.052*** | 0.035*** | 0.017 | 0.007*** | 0.003 | 0.011** | 0.013 | 0.019*** | 0.021*** | 0.009 | 0.029** | 0.038*** | 0.049*** | 0.030*** | 0.025** | 0.033*** | 0.024*** | 0.042*** | 0.041*** |
| Export activities | 0.072*** | 0.075*** | 0.075*** | 0.034 | 0.018** | 0.012 | 0.019* | 0.005 | 0.048*** | 0.037** | 0.056*** | 0.047* | 0.065*** | 0.062*** | 0.082*** | 0.027 | 0.021** | 0.023 | 0.029** | -0.001 |
| Competitive pressure | 0.027*** | 0.027*** | 0.033*** | 0.013 | 0.002 | 0.002 | 0.001 | 0.009 | 0.016*** | 0.017*** | 0.026*** | -0.004 | 0.020*** | 0.022*** | 0.019*** | 0.017 | 0.010*** | 0.004 | 0.021*** | 0.004 |
| Demand expectation | 0.025*** | 0.027*** | 0.027*** | 0.020** | 0.004 | 0.001 | 0.004 | 0.011 | 0.016*** | 0.013** | 0.022*** | 0.010 | 0.028*** | 0.027*** | 0.027*** | 0.032*** | 0.015*** | 0.016*** | 0.014** | 0.014 |
| Foreign company | 0.021 | 0.077 | 0.045 | -0.030 | -0.036** | -0.022*** | -0.035 | -0.039 | -0.018 | 0.029 | -0.009 | -0.047 | 0.034 | 0.086* | 0.060 | -0.013 | -0.033 | -0.002 | -0.011 | -0.066* |
| Baseline innovation probability | 0.38 | 0.29 | 0.42 | 0.52 | 0.06 | 0.03 | 0.06 | 0.09 | 0.18 | 0.14 | 0.20 | 0.40 | 0.31 | 0.23 | 0.34 | 0.44 | 0.13 | 0.08 | 0.14 | 0.35 |
| Observations | 23,237 | 10,704 | 8,627 | 3,906 | 23,250 | 10,714 | 8,631 | 3,905 | 23,254 | 10,715 | 8,632 | 3,907 | 23,241 | 10,707 | 8,628 | 3,906 | 23,242 | 10,710 | 8,629 | 3,903 |
| Overall $R^2$ | 0.211 | 0.166 | 0.188 | 0.225 | 0.075 | 0.053 | 0.085 | 0.078 | 0.103 | 0.096 | 0.101 | 0.111 | 0.203 | 0.157 | 0.194 | 0.217 | 0.134 | 0.115 | 0.123 | 0.137 |

*Notes: The table displays marginal effects from linear probability models with random effects, estimated for different dependent variables (binary indicators for general, new-to-market product, new-to-firm product, incremental product, process innovation) by firm size category (I: full sample; II: 1-9 employees; III: 10-49 employees, IV: 50-249 employees). Further controls include indicators for each observation year, economic sector and federal state. Significance levels are based on robust standard errors and denoted as: * p-value < 0.1, ** p-value < 0.05, *** p-value < 0.01. Source: IAB Establishment Panel, Waves 2009-2019. Data access was provided via remote data execution. DOI: 10.5164/IAB.IABBP9319.de.en.v1.*

## 6. Conclusion

The importance of VET for innovation has gained increased research interest. In this context, it has been empirically shown that VET institutions have a relevant contribution to the functioning of regional innovation systems. It would be expected that the empirical evidence at the company level is analogous to this, although surprisingly this is not the case as only a small or no direct relation between initial VET and innovation has been found at the company level. Hence, there is a need for further empirical research to establish whether and for which types of firms a participation in initial VET results in technological innovation. This study addresses this research gap and provides empirical evidence on the role of initial VET for innovation in SMEs.

In this paper, we provide a conceptual framework for the channels through which initial VET activities may exert a positive impact on innovation in the majority of (less R&D-intensive) SMEs. On this basis, we evaluate the impact of initial VET on technological innovation at the company level using data from the German Employment Agency (the IAB EP dataset). To date, the quantitative testing of the hypothesis on a positive link between initial VET and firm-level innovation is underdeveloped. To our knowledge, the pioneering study of Rupietta and Backes-Gellner (2019) was the first to provide some empirical evidence on this issue. However, their estimates are in contrast to the results obtained by Hodge and Smith (2019) – a study that 'did not find clear evidence that VET student placement could directly contribute to new or significantly new products, services, methods or processes' (p. 16).

In contrast to the findings of Rupietta and Backes-Gellner (2019), our results suggest that the direct associations between initial VET and technological innovation are actually quite weak. In this respect, our study confirms the findings of Hodge and Smith (2019). However, in line with Rupietta and Backes-Gellner (2019), we find that a training firm's initial VET activities are associated, if at all, with production innovation activities and not with process innovation. Moreover, our results suggest that initial VET strengthens the technological innovation capacity of training firms via knowledge diffusion and organizational learning, as already assumed by Hodge and Smith (2019). However, this is only true for very small training companies. In case of microenterprises with fewer than ten employees, initial VET is related to the introduction of (local) new-to-market product innovations if, at the same time, accompanying changes in the training firm's organizational processes support individual learning and intra-firm knowledge creation. We conclude from this that active participation in the VET system primarily promotes the innovation activities of very small firms through knowledge diffusion and organizational learning that enables firms to develop the capacity to absorb new external knowledge.

Our results – which show a relationship between initial VET, organizational learning and technological innovation in small-sized firms – hold relevance for innovation policy. They imply that the participation of microenterprises in the VET system helps to improve its skills and competence portfolio, create structures within the firm that promote organizational learning, and increase absorptive capacities of training companies in terms of technological knowledge from VET institutions. Hence, particularly the smallest among training companies seem to benefit from the knowledge transfer from the VET system. As a result, they should be more likely to succeed in overcoming – at least in part – some of their size-related disadvantages in innovation. Promoting a small firm's engagement in the VET system should therefore not only be regarded by policy-makers as a tool to foster the smooth integration of youth into the regular labour market and secure a supply of skilled workers, but also as a measure of innovation policy towards the small business sector. At the same time, the technological upgrading of vocational schools and training centres should therefore not only be a measure of modern education policy, but also an integral part of an SME-oriented innovation policy.

In terms of future research, there is an ongoing need for further empirical studies to establish the empirical relationships between VET and innovation and hence deliver further evidence for education and innovation policy. In this context, a better understanding of the complex interplay between initial VET, organizational learning and (DUI mode) technological innovation is crucial, e.g. by complementing the findings of the present study using qualitative research methods. In quantitative terms, a key challenge would be to improve the estimation strategy in terms of causality. Although we have tried to avoid the problem of reverse causality as much as possible, we cannot completely rule out the possibility that our results are biased in this respect. This is where future studies could come in. Future research could also investigate whether the type of initial VET matters. Our paper has investigated the link between initial VET and technological innovation under the conditions of a country with a dual VET system. In countries with a full-time school-based VET system, the results might differ to a certain extent, since under the conditions there, VET students have only limited practical phases in companies during their time of training. It would also be interesting to compare the innovation contribution of apprentices with that of vocationally qualified skilled workers. In the present analysis, no relationship was found between initial VET and process innovation. However, from a theoretical point of view, we would expect a positive relation between VET and process innovation outcomes, as the knowledge associated with business process improvements often contains a relatively high degree of tacitness, which should be associated with a greater importance of VET-based learning and skills in the context of process innovation. It seems reasonable to assume that apprentices still have too little experiential knowledge to contribute effectively to process innovation, whereas VET-trained skilled workers have probably already built up precisely this practical experience and strong familiarity with the business processes concerned to make a significant contribution to the introduction of process innovations. Investigating whether this is indeed the case could be a promising avenue for future research efforts.

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**Appendix A.**

Table A1. Descriptive Statistics

| | | All companies | | Training companies | | Non-training companies | |
|---|---|---|---|---|---|---|---|
| | **Description** | **Mean** | **S.D.** | **Mean** | **S.D.** | **Mean** | **S.D.** |
| ***Dependent variables*** | | | | | | | |
| General innovation | 1 if firm conducted product and/or process innovation | 0.38 | 0.49 | 0.46 | 0.49 | 0.33 | 0.47 |
| New-to-market product innovation | 1 if firm conducted new-to-market product innovations | 0.06 | 0.23 | 0.07 | 0.26 | 0.04 | 0.21 |
| New-to-firm product innovation | 1 if firm conducted new-to-firm product innovation | 0.18 | 0.38 | 0.22 | 0.41 | 0.15 | 0.36 |
| Incremental product innovation | 1 if firm conducted product innovation which is not new to the market or new to the firm | 0.31 | 0.46 | 0.37 | 0.48 | 0.26 | 0.44 |
| Process innovation | 1 if firm conducted process innovation | 0.13 | 0.33 | 0.17 | 0.37 | 0.09 | 0.29 |
| ***Explanatory variable*** | | | | | | | |
| Initial VET | 1 if firm employs apprentices (VET students) | 0.44 | 0.50 | 1 | 0 | 0 | 0 |
| Organizational changes | 1 if firm conducted organizational changes | 0.30 | 0.46 | 0.41 | 0.50 | 0.23 | 0.42 |
| ***Control variables*** | | | | | | | |
| Company size | Total number of employees | 32.70 | 47.00 | 53.44 | 56.30 | 16.71 | 29.67 |
| Share of workers with vocational qualification | Employees with completed vocational training in total employment (%) | 0.57 | 0.28 | 0.65 | 0.23 | 0.51 | 0.30 |
| Share of workers with university degree | Employees with higher education in total employment (%) | 0.08 | 0.17 | 0.07 | 0.14 | 0.08 | 0.19 |
| Competitive pressure | 1 for medium / substantial competitive pressure | 2.93 | 1.00 | 3.02 | 0.96 | 2.85 | 1.02 |
| Demand expectation | 1 if company expects increasing business volume next year | 2.05 | 0.59 | 2.08 | 0.62 | 2.03 | 0.57 |
| Foreign company | 1 if company is foreign owned | 0.04 | 0.20 | 0.05 | 0.21 | 0.03 | 0.18 |
| Shortage of skilled workers | 1 if a company reports lack of skilled workers | 0.14 | 0.35 | 0.20 | 0.40 | 0.10 | 0.30 |
| Continuing training | 1 if a company provides continuing training to their employees | 0.63 | 0.48 | 0.79 | 0.41 | 0.50 | 0.50 |
| R&D activities | 1 if a company conducts in-house R&D | 0.07 | 0.26 | 0.11 | 0.31 | 0.05 | 0.21 |
| Investment activities | 1 if a company made investments in 2016 | 0.59 | 0.49 | 0.72 | 0.45 | 0.49 | 0.50 |
| Technical equipment | State of a company’s technical equipment (1 ‘state-of-the-art’ – 4 ‘out of date’) | 2.73 | 0.75 | 2.81 | 0.74 | 2.67 | 0.76 |
| Export activities | 1 for exporting companies | 0.20 | 0.40 | 0.27 | 0.44 | 0.15 | 0.36 |

Source: IAB Establishment Panel, Waves 2009-2019. Data access was provided via remote data execution. DOI: 10.5164/IAB.IABBP9319.de.en.v1.

Table A2. Descriptive statistics by firm size categories

| | | I | | II | | III | | IV | |
|---|---|---|---|---|---|---|---|---|---|
| | **Description** | **Mean** | **S.D.** | **Mean** | **S.D.** | **Mean** | **S.D.** | **Mean** | **S.D.** |
| ***Dependent variables*** | | | | | | | | | |
| General innovation | 1 if firm conducted product and/or process innovation | 0.38 | 0.49 | 0.29 | 0.45 | 0.42 | 0.49 | 0.52 | 0.50 |
| New-to-market product innovation | 1 if firm conducted new-to-market product innovations | 0.06 | 0.23 | 0.03 | 0.18 | 0.06 | 0.25 | 0.09 | 0.29 |
| New-to-firm product innovation | 1 if firm conducted new-to-firm product innovation | 0.18 | 0.38 | 0.14 | 0.35 | 0.20 | 0.40 | 0.23 | 0.42 |
| Incremental product innovation | 1 if firm conducted product innovation which is not new to the market or to the firm | 0.31 | 0.46 | 0.23 | 0.42 | 0.34 | 0.47 | 0.44 | 0.50 |
| Process innovation | 1 if firm conducted process innovation | 0.13 | 0.33 | 0.08 | 0.26 | 0.14 | 0.35 | 0.21 | 0.41 |
| ***Explanatory variable*** | | | | | | | | | |
| Initial VET | 1 if firm employs apprentices (VET students) | 0.44 | 0.50 | 0.19 | 0.39 | 0.55 | 0.50 | 0.78 | 0.42 |
| Organizational changes | 1 if firm conducted organizational changes | 0.30 | 0.46 | 0.17 | 0.37 | 0.36 | 0.48 | 0.51 | 0.50 |
| ***Control variables*** | | | | | | | | | |
| Company size | Total number of employees | 32.70 | 47.00 | 4.47 | 2.32 | 23.90 | 11.09 | 110.84 | 52.69 |
| Share of workers with vocational qualification | Employees with completed vocational training in total employment (%) | 0.57 | 0.28 | 0.48 | 0.28 | 0.64 | 0.26 | 0.63 | 0.25 |
| Share of workers with university degree | Employees with higher education in total employment (%) | 0.08 | 0.17 | 0.05 | 0.14 | 0.09 | 0.18 | 0.12 | 0.19 |
| Competitive pressure | 1 for medium / substantial competitive pressure | 2.93 | 1.00 | 2.87 | 0.99 | 2.96 | 0.99 | 2.98 | 1.04 |
| Demand expectation | 1 if company expects increasing business volume next year | 2.05 | 0.59 | 2.02 | 0.56 | 2.07 | 0.61 | 2.08 | 0.64 |
| Foreign company | 1 if company is foreign owned | 0.04 | 0.20 | 0.02 | 0.15 | 0.03 | 0.18 | 0.10 | 0.30 |
| Shortage of skilled workers | 1 if a company reports lack of skilled workers | 0.14 | 0.35 | 0.07 | 0.26 | 0.18 | 0.38 | 0.24 | 0.43 |
| Continuing training | 1 if a company provides continuing training to their employees | 0.63 | 0.48 | 0.43 | 0.49 | 0.73 | 0.45 | 0.90 | 0.29 |
| R&D activities | 1 if a company conducts in-house R&D | 0.07 | 0.26 | 0.03 | 0.16 | 0.08 | 0.27 | 0.16 | 0.37 |
| Investment activities | 1 if a company made investments in 2016 | 0.59 | 0.49 | 0.43 | 0.50 | 0.67 | 0.47 | 0.79 | 0.40 |
| Technical equipment | State of a company's technical equipment (1 'state-of-the-art' – 4 'out of date') | 2.73 | 0.75 | 2.67 | 0.77 | 2.76 | 0.75 | 2.80 | 0.72 |
| Export activities | 1 for exporting companies | 0.20 | 0.40 | 0.09 | 0.28 | 0.24 | 0.43 | 0.42 | 0.49 |

Notes: Firm size category (I: full sample; II: 1-9 employees; III: 10-49 employees, IV: 50-249 employees). Source: IAB Establishment Panel, Waves 2009-2019. Data access was provided via remote data execution. DOI: 10.5164/IAB.IABBP9319.de.en.v1.

Table A3. Correlation Matrix

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Initial VET | 1 | | | | | | | | | | | | | |
| Organizational changes | 0.187 | 1 | | | | | | | | | | | | |
| Company size | 0.388 | 0.246 | 1 | | | | | | | | | | | |
| Share qualified workers | 0.248 | 0.087 | 0.139 | 1 | | | | | | | | | | |
| Share university graduates | -0.034 | 0.112 | 0.176 | -0.295 | 1 | | | | | | | | | |
| Shortage of skilled workers | 0.139 | 0.102 | 0.147 | 0.112 | 0.043 | 1 | | | | | | | | |
| Continuing training | 0.292 | 0.225 | 0.324 | 0.221 | 0.207 | 0.136 | 1 | | | | | | | |
| R&D activities | 0.117 | 0.172 | 0.204 | -0.001 | 0.227 | 0.067 | 0.113 | 1 | | | | | | |
| Investment activities | 0.224 | 0.202 | 0.237 | 0.149 | 0.100 | 0.096 | 0.273 | 0.124 | 1 | | | | | |
| Technical equipment | 0.090 | 0.054 | 0.053 | 0.082 | 0.061 | 0.034 | 0.173 | 0.031 | 0.163 | 1 | | | | |
| Export activities | 0.145 | 0.184 | 0.288 | 0.070 | 0.153 | 0.056 | 0.108 | 0.380 | 0.144 | -0.016 | 1 | | | |
| Competitive pressure | 0.085 | 0.115 | 0.023 | 0.071 | -0.115 | 0.047 | -0.021 | 0.072 | 0.033 | 0.000 | 0.108 | 1 | | |
| Demand expectation | 0.043 | 0.057 | 0.033 | 0.006 | 0.020 | 0.090 | 0.060 | 0.036 | 0.056 | 0.056 | 0.044 | -0.039 | 1 | |
| Foreign company | 0.034 | 0.074 | 0.170 | 0.000 | 0.084 | 0.021 | 0.049 | 0.134 | 0.014 | -0.038 | 0.190 | 0.079 | 0.002 | 1 |

Source: IAB Establishment Panel, Wave 2019-2019. Data access was provided via remote data execution. DOI: 10.5164/IAB.IABBP9319.de.en.v1.

Table A4. Regression results (fixed effects)

| | Linear probability models | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | General innovation | | | | New-to-market product innovation | | | | New-to-firm product innovation | | | | Incremental product innovation | | | | Process innovation | | | |
| | I | II | III | IV | I | II | III | IV | I | II | III | IV | I | II | III | IV | I | II | III | IV |
| Initial VET | 0.017 | 0.005 | 0.008 | 0.027 | -0.002 | -0.002 | -0.003 | -0.036 | 0.009 | 0.004 | -0.004 | 0.020 | 0.009 | 0.002 | 0.008 | 0.019 | 0.011 | 0.004 | 0.011 | -0.004 |
| Organizational changes | 0.100*** | 0.094*** | 0.084*** | 0.089** | 0.012* | 0.008 | 0.013 | 0.006 | 0.051*** | 0.056*** | 0.022 | 0.072** | 0.078*** | 0.062*** | 0.079*** | 0.077* | 0.051*** | 0.039*** | 0.054*** | 0.046 |
| VET#ORGA | -0.031** | -0.004 | -0.013 | -0.040 | 0.016* | 0.046** | 0.010 | 0.021 | -0.015 | 0.010 | 0.008 | -0.035 | 0.018 | 0.007 | -0.017 | -0.033 | 0.008 | 0.022 | -0.000 | 0.022 |
| **Controls** | | | | | | | | | | | | | | | | | | | | |
| Company size | 0.001 | 0.009* | 0.002* | 0.000 | -0.000 | -0.004* | 0.002 | -0.000 | -0.000 | 0.008** | -0.001 | -0.001 | 0.001* | 0.007* | 0.003** | 0.001 | 0.001* | 0.006* | 0.000 | 0.000 |
| Share qualified workers | 0.034* | 0.026 | 0.004 | 0.054 | 0.010 | 0.008 | -0.012 | 0.122*** | 0.014 | 0.024 | -0.032 | 0.050 | 0.033* | 0.009 | 0.026 | 0.110 | 0.013 | 0.017 | -0.016 | -0.006 |
| Share of university graduates | 0.047 | -0.016 | 0.112 | 0.225 | 0.028 | -0.002 | 0.043 | 0.286* | 0.046 | 0.005 | 0.059 | 0.253 | -0.003 | -0.030 | 0.012 | 0.134 | 0.114*** | 0.102** | 0.147** | 0.044 |
| Shortage of skilled workers | 0.002 | -0.014 | 0.006 | 0.008 | -0.006 | 0.002 | -0.011 | -0.003 | 0.008 | 0.002 | 0.011 | 0.003 | -0.009 | -0.022 | -0.005 | -0.009 | 0.009 | 0.008 | 0.004 | 0.020 |
| Continuing training | 0.048*** | 0.052*** | 0.044*** | 0.010 | 0.008** | 0.006 | 0.015** | -0.001 | 0.020*** | 0.024*** | 0.008 | 0.026 | 0.044*** | 0.041*** | 0.049*** | 0.012 | 0.020*** | 0.022*** | 0.023** | 0.008 |
| R&D activities | 0.111*** | 0.126*** | 0.107*** | 0.105*** | 0.091*** | 0.094** | 0.093*** | 0.087*** | 0.105*** | 0.117*** | 0.093*** | 0.097*** | 0.126*** | 0.131*** | 0.133*** | 0.097*** | 0.088*** | 0.109** | 0.063** | 0.100*** |
| Investment activities | 0.061*** | 0.063*** | 0.048*** | 0.067*** | 0.011*** | 0.014*** | 0.003 | 0.015 | 0.034*** | 0.034*** | 0.035*** | 0.042* | 0.060*** | 0.055*** | 0.061*** | 0.075*** | 0.033*** | 0.032*** | 0.032*** | 0.032* |
| Technical equipment | 0.032*** | 0.045*** | 0.020** | 0.021 | 0.091*** | 0.000 | 0.007 | 0.014 | 0.105*** | 0.014** | 0.000 | 0.037*** | 0.126*** | 0.046*** | 0.018** | 0.039*** | 0.088*** | 0.017*** | 0.029*** | 0.049*** |
| Export activities | 0.013 | 0.006 | 0.031 | -0.046 | -0.008 | -0.010 | -0.011 | -0.032 | 0.022* | 0.012 | 0.038* | -0.010 | 0.010 | -0.007 | 0.038* | -0.047 | 0.006 | 0.004 | 0.020 | -0.046 |
| Competitive pressure | 0.021*** | 0.021*** | 0.027*** | 0.010 | 0.001 | 0.003 | -0.004 | 0.006 | 0.012*** | 0.013*** | 0.020*** | -0.002 | 0.015*** | 0.015*** | 0.018** | 0.016 | 0.008** | 0.006 | 0.014** | 0.001 |
| Demand expectation | 0.021*** | 0.020*** | 0.024*** | 0.015 | 0.003 | 0.000 | 0.005 | 0.001 | 0.015*** | 0.011* | 0.023*** | 0.002 | 0.024*** | 0.019*** | 0.025*** | 0.027*** | 0.009*** | 0.014*** | 0.006 | 0.007 |
| Foreign company | 0.004 | 0.121** | 0.011 | -0.091* | -0.050* | -0.007 | -0.073 | -0.044 | -0.000 | 0.065 | -0.009 | -0.100 | 0.004 | 0.082* | 0.036 | -0.078 | -0.040 | 0.035 | -0.023 | -0.110 |
| Baseline innovation probability | 0.38 | 0.29 | 0.42 | 0.52 | 0.06 | 0.03 | 0.06 | 0.09 | 0.18 | 0.14 | 0.20 | 0.40 | 0.31 | 0.23 | 0.34 | 0.44 | 0.13 | 0.08 | 0.14 | 0.35 |
| Observations | 25,927 | 11,947 | 9,628 | 4,352 | 25,944 | 11,958 | 9,635 | 4,351 | 25,949 | 11,960 | 9,636 | 4,353 | 25,931 | 11,951 | 9,628 | 4,352 | 25,934 | 11,953 | 9,632 | 4,349 |
| Overall $R^2$ | 0.153 | 0.098 | 0.125 | 0.087 | 0.057 | 0.036 | 0.052 | 0.030 | 0.056 | 0.049 | 0.042 | 0.025 | 0.141 | 0.088 | 0.116 | 0.077 | 0.096 | 0.063 | 0.079 | 0.073 |

*Notes: The table displays marginal effects from linear probability models with fixed effects, estimated for different dependent variables (binary indicators for general, new-to-market product, new-to-firm product, incremental product, and process innovation) by company size classes (I: full sample; II: 1-9 employees; III: 10-49 employees, IV: 50 or more employees). Further controls include indicators for each observation year. Significance levels are based on robust standard errors and denoted as: * p-value < 0.1, ** p-value < 0.05, *** p-value < 0.01.* Source: IAB Establishment Panel, Waves 2009-2019. Data access was provided via remote data execution. DOI: 10.5164/IAB.IABBP9319.de.en.v1.