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Task allocation and innovation: Revisiting the role of vocational education and training in manufacturing firms

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ifh Working Paper No. 47/2025*

Task allocation and innovation: revisiting the role of vocational education and training in manufacturing firms

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Abstract

This paper examines the role of vocational education and training (VET) in innovation by comparing the VET workforce's participation in innovation with that of university graduates, such as scientists and engineers. Using individual-level data from the German manufacturing sector, we distinguish between initial VET qualifications (acquired through dual apprenticeships) and higher VET qualifications (such as master craftsmen or technicians). The results confirm that university graduates dominate continuous research and development (R&D) activities. However, VET-qualified employees – especially those with higher VET qualifications – play a substantial role in both the invention and implementation phases of the firm's innovation process. Initial VET graduates are particularly active in implementation, notably in introducing new machinery, equipment, and technologies. Higher VET graduates are crucial in bridging the gap between R&D and the shop floor, facilitating knowledge transfer between different qualification groups. These participation patterns vary with firm size, with large firms showing clearer task allocation and specialisation. Overall, the paper's findings highlight that innovation in manufacturing relies on the complementary strengths of vocational and academic qualifications, with implications for policy, management, and future research.

JEL: I2; J24; M53; O15; O30; O31

Keywords: Innovation; Vocational education and training (VET); Diversity; Skills; Firm size

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1. Introduction

The role of workforce qualifications and skills in driving a firm's innovativeness has attracted growing research interest (e.g. Høyrup 2010; Andries and Czarnitzki 2014; Bolli, Renold, and Wörter 2018; Bäckström and Bengtsson 2019; Mason, Rincon-Aznar, and Venturini 2020). While much of this research focuses on academically trained personnel, such as scientists and engineers (hereafter referred to as '*university graduates*'), recent studies have begun to emphasize the innovation activities of individuals with vocational education and training (VET) qualifications (e.g. Toner 2010; Brunet Icart and Rodríguez-Soler 2017; Albizu et al. 2017; Rupietta and Backes-Gellner 2019; Alhusen and Bennat 2021; Lewis 2023).

In this context, empirical findings from small and medium-sized enterprises (SMEs) in the Spanish manufacturing sector show that VET-qualified employees contribute to firm-level innovation, particularly in terms of process and incremental product innovation. Their innovation participation is particularly strong when firms provide supportive organizational conditions that encourage interactive learning and employee involvement (Albizu et al. 2017; Brunet Icart and Rodríguez-Soler 2017). Moreover, close collaboration between firms and nearby VET institutions appears to further promote corresponding innovation activities, underlining the important role of the VET system in regional innovation dynamics (Lund and Karlsen 2020; Hädrich, Reher, and Thomä 2024; Friedrich and Kagel 2025).

While previous studies have focused on SMEs, our study also considers large manufacturing firms in order to provide a more comprehensive picture of the relationship between VET qualifications and innovation. Conceptually, it is often assumed that university graduates, particularly those working in research and development (R&D), are primary drivers of innovation, especially in large firms. By contrast, VET-qualified employees are expected to be especially important for innovation in smaller, less R&D-intensive companies (e.g., Acs and Audretsch 1988; Van Dijk et al. 1997; Leiponen 2005; Freel 2005; Jensen et al. 2007; Thomä 2017). In practice, however, innovation in both small and large firms should often involve employees with different qualifications working together and learning from each other. Consequently, educational workforce diversity can have a positive impact on a firm's innovativeness (Østergaard et al. 2011; McGuirk and Jordan 2012).

In line with this, studies by Bolli, Renold & Wörter (2018) and Mason, Rincon-Aznar & Venturini (2020) suggest that the role of VET-qualified employees in innovation should not be analyzed in isolation. Rather, comparisons with other qualification groups – especially university graduates – are needed to better understand how different educational backgrounds complement each other in innovation processes. Firm size may play a decisive role here. Larger companies typically have a more specialized workforce of experts in various innovation-related fields. This diversity should enable a clearer division of labor and more structured task allocation between qualification groups and departments, which in turn may foster innovation. By contrast, individuals in smaller firms tend to have broader skill sets than those in larger firms, as they are often required to take on multiple roles (Rothwell 1989; Nooteboom 1994; Freel 2005).

Against this background, our study investigates the innovation participation of VET-qualified employees in relation to university graduates, and how this varies depending on firm size. Our contribution to the literature is twofold:

First, using data from a repeated cross-sectional survey of employed persons in Germany, we differentiate between the activities of VET-qualified employees and university graduates in both the invention and implementation phases of a firm's innovation process. This distinction, as highlighted by Bolli, Renold, and Wörter (2018), is particularly useful for analyzing how different qualifications and skills complement each other during specific stages of business innovation. In this regard, our individual-level data – relating to employed persons and their workplaces – offers a nuanced perspective on how VET-qualified individuals and university graduates participate in their firm's innovation activities. Unlike previous studies that use firm-level data, this approach allows us to examine the innovation activities of the VET workforce in greater detail and with more contextual depth.

Second, our analysis distinguishes not only between university graduates and VET-qualified personnel, but also between different qualification groups within the VET workforce. Specifically, we differentiate between individuals who have completed initial VET through a dual apprenticeship as their highest vocational qualification ('*IVETs*'), and those with higher vocational qualifications – such as master craftsmen or technicians – from here referred to as '*HVETs*'. While university graduates are widely used as a standard indicator of a firm's absorptive capacity (OECD/Eurostat 2018), it is often assumed that the innovation participation of VET-qualified employees is concentrated in the implementation rather than the invention phase of business innovation processes. However, findings by Mason, Rincon-Aznar, and Venturini (2020) challenge this assumption, suggesting that HVETs may also play a significant role in the invention phase. Their involvement at this stage could highlight the importance of different types of tertiary education in encouraging creativity and generating new ideas and solutions. Furthermore, HVETs also often supervise IVETs during the implementation phase, guide technological improvement

processes on the shop floor and can act as vital intermediaries between R&D departments and production units (Finegold and Wagner 1998; Mason 2000; Mason, Rincon-Aznar and Venturini 2020; Weidner, Som and Horvat 2023). These multifaceted roles may suggest that HVETs participate in innovation in ways that differ systematically from IVETs. Understanding these differences is crucial and calls for further empirical investigation.

The remainder of this paper is organized as follows: Section 2 outlines the conceptual framework of our study and proposes a set of hypotheses concerning the participation of the VET-workforce and university graduates in innovation. Section 3 describes the dataset, while Section 4 presents the empirical analysis. Section 5 summarises and discusses our findings. On this basis, we formulate implications for policy, management and future research.

2. Conceptual background

From a theoretical perspective, VET qualifications offer several potential advantages for firm-level innovation, particularly in manufacturing industries. Toner (2010) was among the first to elaborate on this, emphasizing the role of VET-qualified individuals such as skilled production workers, tradespeople and technicians. Focusing on the Australian context, he argues that this qualification group contributes significantly to innovation in both R&D and non-R&D areas. Their innovation participation is linked to experience-based knowledge processes such as learning by doing and using, the development and application of problem-solving skills, and involvement in incremental innovation. Building on this, Toner (2010) highlights the importance of the VET system in terms of technology diffusion throughout the economy.

Building on Toner's (2010) seminal work, subsequent studies have further developed these theoretical considerations by focusing on the specific skills of the VET workforce. In particular, they highlight the ability of VET-qualified employees to communicate effectively with university graduates such as scientists and engineers on innovation-related matters. This ability stems from their comparatively high level of training, which combines both practical and theoretical knowledge components – a characteristic feature of countries with well-established dual VET systems like Germany or Switzerland that combine company- and school-based learning (e.g. Ruth and Deitmer 2010; EFI 2014). This kind of 'mutual understanding' can facilitate intra-firm knowledge exchange (i.e. learning by interaction) between R&D departments and other areas such as production and marketing (Flåten, Isaksen, and Karlsen 2015; Backes-Gellner and Lehnert 2023). In a dual VET system, apprentices gain hands-on experience during their training, acquiring early insight into internal company processes, which they can later deepen as skilled workers. At the same time, this practical learning is complemented by formal instruction in vocational schools, resulting in a combination of experiential and abstract-theoretical knowledge. This blend supports innovation-enhancing collaboration between VET-qualified employees and university graduates during the firm's innovation process (Ruth and Deitmer 2010; Thomä 2017).

Due to their unique skill set, members of the VET workforce are well equipped to engage in creative problem-solving and to handle complexity and unpredictability in operational contexts – factors that are particularly relevant for (non-R&D-based) innovation (Flåten, Isaksen, and Karlsen 2015; Pfeiffer 2018; Thomä 2017). Their experiential knowledge should be especially valuable at the intersection of incremental product improvement, production technology, new machinery and process planning (Toner 2010). In collaboration with university graduates, VET-qualified employees can contribute to both R&D and non-R&D innovation activities, including areas such as prototyping and design. In doing so, they participate in driving process and product innovation – an effect that has been empirically demonstrated in the above-mentioned studies on Spanish manufacturing SMEs (Albizu et al. 2017; Brunet Icart and Rodríguez-Soler 2017). Such activities are particularly likely when workplaces are designed to encourage learning. This includes settings that encourage interactive exchange, allow for learning through trial and error, and promote individual responsibility, thereby providing employees with the creative freedom needed for innovation to flourish (Flåten, Isaksen, and Karlsen 2015; Matthies, Thomä, and Bizer 2025).

In this context, we argue that it is useful to distinguish the innovation participation of VET-qualified individuals from that of university graduates, and to further differentiate between subgroups within the VET workforce based on their specific roles in the innovation process. Individuals with higher VET qualifications such as master craftsmen or technicians (HVETs) can be expected to be a relevant source of a firm's absorptive capacity (Hirsch-Kreinsen 2008; Hirsch-Kreinsen, 2015; Thomä and Zimmermann 2020; Weidner, Som, and Horvat 2023). They are therefore likely to have an important function in generating and testing new ideas during the invention phase of a firm's innovation process in interaction with university graduates such as scientists and engineers (Bolli, Renold, and Wörter 2018; Mason, Rincon-Aznar, and Venturini 2020).

In contrast to university graduates – whose dominant role in formal R&D suggests a strong focus on the invention phase – HVETs can be assumed to play a mediating role within the internal learning environment of manufacturing

firms; that is, between R&D and the production unit, or more broadly, between university graduates and IVETs. This is because, at least in countries with well-established VET systems, HVETs combine a high level of scientific-theoretical knowledge related to innovative ideas with extensive practical experience in their implementation – whether in production processes, prototyping, or the operation of the necessary equipment and machinery. This dual competence should enable them to bridge and translate between different qualification groups within the company, particularly in the context of manufacturing industries. For example, in roles such as first-line managers or process developers, HVETs are well positioned to facilitate knowledge exchange between scientists from the R&D department and skilled production workers on the shop floor. In doing so, they can help to reduce coordination and communication costs arising from conflict, mistrust, or misunderstanding (Finegold and Wagner 1998; Mason 2000; Kirner and Som 2015; Bolli, Renold, and Wörter 2018; Weidner, Som, and Horvat 2023). Accordingly, HVETs are potential “boundary spanners” (Weidner, Som, and Horvat 2023) between the various qualification groups involved in the invention and implementation phases of a firm’s innovation process. By fulfilling their multiple roles in the invention and implementation phase of a firm’s innovation process, HVETs should therefore help to unlock the innovation-enhancing potential of educational workforce diversity (Østergaard, Timmermans, and Kristinsson 2011).

Compared to university graduates and HVETs, the participation of IVETs is more likely to be concentrated in the implementation phase of a firm’s innovation process. They are often directly involved in the practical application of new technologies and procedures, as they operate innovation-relevant machinery, equipment, and materials on the shop floor (Toner 2010; Mason, Rincon-Aznar, and Venturini 2020). However, their everyday work often involves routine tasks (Pfeiffer 2018). This is why we expect their overall contribution to new ideas and creative solutions to be more limited than that of HVETs or university graduates, meaning they are less likely to participate in the invention phase. Nonetheless, their hands-on experience – gained through learning by doing and using – can generate valuable feedback for upstream business units such as R&D. This experiential feedback, particularly during the introduction of new or significantly modified products and processes, can, for example, serve as an important source of incremental improvements and refinements (EFI 2014; Thomä 2017; Mason, Rincon-Aznar, and Venturini 2020).

To summarise, we expect university graduates to be primarily involved in the invention phase of a firm’s innovation process, whereas IVETs are likely to play a key role in the implementation phase. By contrast, HVETs are expected to act in both domains, participating both in invention and implementation. In this way, the innovation participation of the VET workforce can be expected to complement that of university graduates in distinct and meaningful ways. The organisational context – particularly the size of the firm – may play a crucial role in shaping this pattern. As previously noted, previous studies have demonstrated the innovation contributions of the VET workforce in the context of manufacturing SMEs (Albizu et al. 2017; Brunet Icart and Rodríguez-Soler 2017). However, the benefits of educational workforce diversity are likely to be especially pronounced in case of larger firms. It is well established that innovation processes and their underlying mechanisms differ systematically with firm size (Acs and Audretsch 1988; Van Dijk et al. 1997). At the same time, economic research has long shown that increasing firm size tends to go hand in hand with greater division of labour (Groenewegen 2018). Against this backdrop, it is hardly surprising that firm-level innovation activities are often characterised by a functional allocation of tasks (Chakrabarti and Hauschildt 1989), which is likely to be more differentiated in large firms. One of their main innovation-related advantages lies in their capacity to employ a broad range of highly qualified specialists across different innovation-relevant domains (Rothwell 1989; Nooteboom 1994; Jensen et al. 2007). This increases the potential for productive interaction between diverse qualification profiles and departments. In contrast, smaller firms – due to a flatter organisational structure and fewer functional divisions – often rely more heavily on individuals who perform multiple innovation-related roles (e.g., the business owners; see Runst and Thomä 2022). Therefore, the expected division of innovations-related tasks among university graduates, IVETs, and HVETs is likely to be more pronounced in large firms.

Hence, we derive the following four hypotheses:

H1: University graduates primarily participate in the invention phase of business innovation.

H2: IVETs primarily participate in the implementation phase of business innovation.

H3: HVETs are involved in both the invention and implementation phases.

H4: The task allocation assumed in H1 to H3 become more pronounced as firm size increases.

3. Data and Method

3.1. Data

In order to examine our hypotheses, we use data from the 2006, 2012 and 2018 BIBB/BAuA Employment Surveys as an independently pooled cross-sectional data set.¹ These provides representative employment data from Germany that are collected jointly by the Federal Institute for Vocational Education and Training (BIBB) and the Federal Institute for Occupational Safety and Health (BAuA). The BIBB/BAuA Employment Surveys are conducted every six years and are based on random samples of the entire German labour force, defined as persons who work at least 10 hours per week and are older than 15 years. The surveys contain detailed information on the qualifications and working conditions of the respondents, providing a comprehensive and representative picture of aspects such as educational level, qualifications, tasks, knowledge requirements, working conditions, individual responsibilities or career changes. Our sample is restricted to the working population aged 15–65, with a focus on employed individuals in the manufacturing industry.

Our sample contains nearly 13,500 observations. 55.1% of the respondents are IVETs, 12.0% HVETs and 13.9% are university graduates (Table 1). In order to enable a clear comparison between these three groups of qualifications, they are defined as follows: IVETs are individuals who have completed an initial VET programme through a dual apprenticeship, but who do not hold an academic degree from a traditional university or a university of applied sciences ('university degree'). Similarly, HVETs are individuals with advanced vocational qualifications, such as master craftsmen or technicians, who also do not hold a university degree. University graduates, on the other hand, are defined as individuals who hold an academic degree from a university or a university of applied sciences and do not have an IVET- or HVET-related vocational qualification.² Table 1 also describes the remaining two qualification groups, which are used as the reference case ('No professional qualification') and a control variable ('Other qualification') in the regressions.

Table 1. Descriptive statistics on the main variables (n = 13,486)

Description		Percent
<i>Activities in the invention phase (dependent variable: categorical)</i>		
No activity	0 if there is no invention phase activity	19.15
Occasional innovator without R&D	1 if respondent sometimes improves existing processes or tries out something new at work (without carrying out R&D)	27.03
Continuous innovator without R&D	2 if respondent often improves existing processes or tries out something new at work (without carrying out R&D)	11.49
Occasional R&D	3 if respondent is sometimes involved in development/research/design at work	25.17
Continuous R&D	4 if respondent is often involved in development/research/design at work)	17.17
<i>Activities in the implementation phase (dependent variable: dummies)</i>		
Products / materials	1 if new or significantly changed products or materials have been introduced in the respondent's immediate working environment in the last two years	39.39
Services	1 if new or significantly changed services have been provided in the respondent's immediate working environment in the last two years	25.86
Production / process technologies	1 if new production or process technologies have been introduced in the respondent's immediate working environment in the last two years	51.67
Machines / equipment	1 if new machinery and equipment has been introduced into the respondent's immediate working environment in the last two years	53.81
Organizational practices	1 if the respondent's immediate working environment has undergone significant restructuring or reorganisation in the last two years	48.10

¹ BIBB/BAuA Employment Surveys 2006 (Hall and Tiemann 2021), 2012 (Hall et al. 2020a), 2018 (Hall et al. 2020b).

² One could argue that, despite the academic nature of their educational program, graduates from universities of applied sciences ('FH graduates') have something in common with VET graduates due to their relatively strong practical orientation. Consequently, some of the arguments in favor of VET qualifications may also apply to this qualification group. Therefore, as a robustness check, the core element of the following empirical analysis is repeated, excluding FH graduates from the 'university graduates' category. The results are very similar to those of the main analysis (see Section 4.3), suggesting that FH graduates can continue to be included in this group.

Table 1. (continued)

<i>Combination of core activities at the individual level (dependent variable: categorical)</i>		
No core activity	1 if respondent is not involved in core activities of the invention and implementation phases	19.21
Only core invention phase activity	1 if respondent is only involved in occasional or continuous R&D	8.99
Only core implementation phase activity	1 if respondent is only involved in core implementation phase activities (i.e., introduction of products/materials, production/process technologies, machines/equipment)	38.46
Both core invention and implementation phase activities	1 if respondent is involved both in occasional/continuous R&D, as well as core implementation phase activities	33.35
<i>Qualification (main explanatory variable: categorical)</i>		
No professional qualification	1 if respondent has not acquired a professional qualification	6.62
IVETs	1 if respondent has completed initial VET through a dual apprenticeship and does not hold a university degree	55.12
HVETs	1 if the highest vocational qualification is completion of a higher VET qualification (e.g. master craftsman, technician, etc.) and no university degree is held	11.96
University graduates	1 if respondent holds an academic degree from a university or a university of applied sciences, and no VET qualification has been obtained	13.93
Other qualification	1 if respondent is neither an IVET nor a HVET or university graduate as defined above (i.e. those with any other professional qualification; or people holding both a university degree and a IVET- or HVET-related vocational qualification)	12.38
<i>Firm size (categorical)</i>		
Micro firms	1 if the respondent's company has a workforce of between 1 and 9 persons	10.49
Small firms	2 if the respondent's company has a workforce of between 10 and 49 persons	17.38
Medium-sized firms	3 if the respondent's company has a workforce of between 50 and 249 persons	25.03
Large firms	4 if the respondent's company has a workforce of 250 persons or more	47.09

Notes: See Table A1 in the appendix for descriptive statistics on the control variables.

Two different indicators are used to capture invention phase activities as a dependent variable for the regressions. The first indicates how often a respondent researches, develops or designs something as part of his or her job, which we summarise under the term 'R&D'³. In addition, to cover participation in non-R&D-based innovation activities during the invention phase, we resort to a second indicator. This covers individuals who, while stating that they are not engaged in R&D, at the same time frequently or at least sometimes improve existing processes or try out something new as part of their work – suggesting a relatively high level of creativity. On this basis, the following five-category variable is formed to cover the invention phase (see Table 1): 'No activity', 'Occasional innovator without R&D', 'Continuous innovator without R&D', 'Occasional R&D', and 'Continuous R&D'.

To cover the implementation phase as a dependent variable, we can use data on the participation in product and process innovation activities (see Table 1). In this respect, respondents were asked whether any innovative changes had taken place in their immediate working environment in the last two years. For product innovation, we distinguish between the introduction of new or significantly changed products or materials (39.4%) and the provision of new or significantly changed services (25.9%). In the case of process innovation activities, we have information on the introduction of new manufacturing or process technologies (51.7%), of new machines or equipment (53.8%) and of new organizational practices (48.1%).

In order to empirically test the above hypotheses in more detail, we construct a further dependent variable in relation to the individual combination of activities undertaken during the invention and implementation phases of

³ It should therefore be noted that, in line with Godin (2006), we also include design activities under the R&D label.

business innovation. This variable indicates whether an individual engages in core activities associated with one or both of these phases, or neither. Drawing on the theoretical considerations in Section 2 (as well as the empirical evidence in Sections 4.1 and 4.2), we assume that there is a distinct division of labor between qualification groups with regard to interactions between the R&D department and the shop floor in manufacturing firms. Against this backdrop, the variable 'Combination of core activities at the individual level' reflects how individuals engage within these two innovation-critical areas of their company. It consists of four categories (see Table 1): 'No core activity', 'Only core invention phase activity', 'Only core implementation phase activity', and 'Both core invention and implementation phase activities'.

The firm size variable, as it is used in the empirical analysis, is also described in Table 1. In line with the European Commission's common SME definition, we distinguish between the following categories of firm size: micro, small, medium-sized and large. The descriptive statistics and descriptions of the further variables can be found in Table A1 in the Appendix.

3.2. Method

Two types of regression model are employed in the empirical analysis. First, sections 4.1 and 4.3 use multinomial logistic regression to estimate the probability of the two categorical outcome variables 'Activities in the invention phase' and 'Combination of core activities at the individual level'. These models are specified as follows:

$$(1) \log \left(\frac{P(Y=j)}{P(Y=0)} \right) = \beta_{j0} + \beta_{j1} \text{Qualification}_i + \beta_{j2} \text{Size}_i + \beta_{j3} (\text{Qualification}_i \times \text{Size}_i) + \theta_j X_i + \delta_j D_t + \epsilon_{ijt}$$

where 'Y' represents the categorical outcome variable ($Y \in \{0, \dots, j\}$). 'Qualification' refers to the qualification groups, 'Size' is the firm size category, and 'Qualification \times Size' denotes the interaction term between these two types of variables. 'X' is a vector of the further variables (age, gender, nationality, East Germany and manufacturing industry) and 'D' captures dummies for the survey years 2012 and 2018, with 2006 as the reference case. Robust standard errors are used.

Second, in Section 4.2 we estimate a set of logistic regression models to assess the likelihood of different activities in the implementation phase ('Y = 1'). These models are specified as:

$$(2) \log \left(\frac{P(Y=1)}{1-P(Y=1)} \right) = \beta_0 + \beta_1 \text{Qualification}_i + \beta_2 \text{Size}_i + \beta_3 (\text{Qualification}_i \times \text{Size}_i) + \theta X_i + \delta D_t + \epsilon_{it}$$

where the further description is analogous to model equation (1).

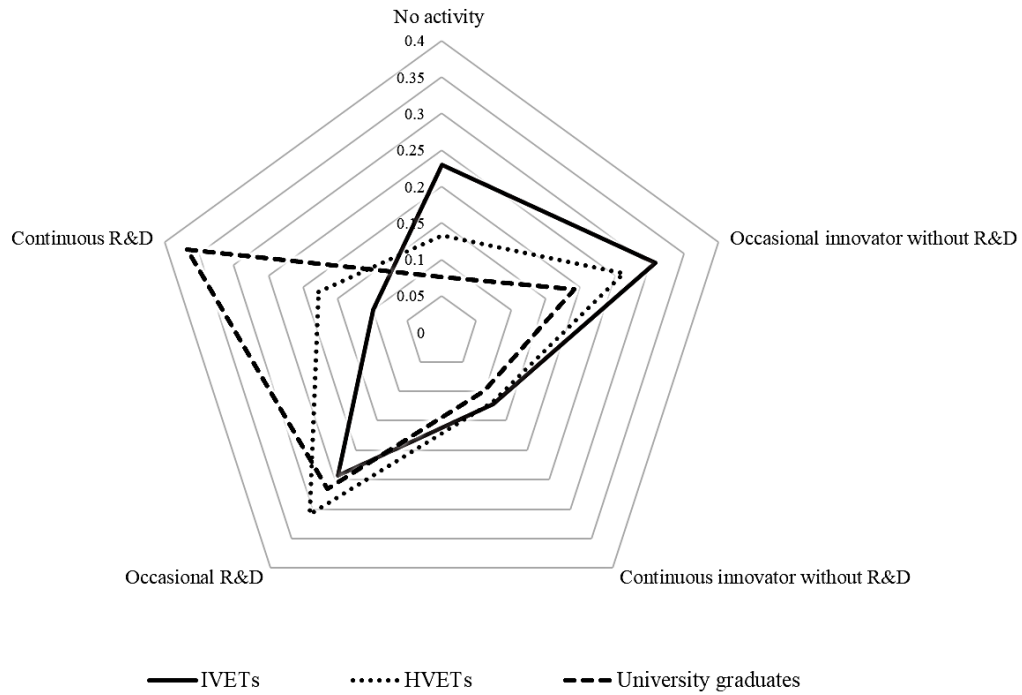
The detailed regression results can be found in the appendix (see Tables A2, A4 and A6). Based on these results, we have estimated the average predicted probabilities (i.e., the predicted margins) for each outcome in relation to the three qualification groups: IVETs, HVETs and university graduates. Spider diagrams showing these estimates can be found in Sections 4.1 to 4.3. These are absolute probabilities, meaning that each value must be considered in isolation, rather than in relation to a reference category. In the subsequent analysis, we compared these values across qualification groups to assess, for example, whether HVETs have a higher probability of participating in a specific innovation activity than university graduates, or vice versa. The interaction with firm size is also taken into account at this stage of the empirical analysis. This enables us to compare the predicted probabilities of innovation participation across qualification groups at different firm size levels.

4. Results

4.1. Activities in the invention phase

Figure 1 presents the predicted probabilities of IVETs, HVETs, and university graduates participating in the invention phase. Complementary to this, Table A3 in the Appendix tests the statistical significance of the pairwise differences between these probabilities and examines whether they vary by firm size.

Figure 1. Predicted probabilities for participation of individuals in invention phase activities, differentiated by professional qualification



Notes: Based on multinomial logit regression results for invention phase activities (see Table A2 in the appendix).

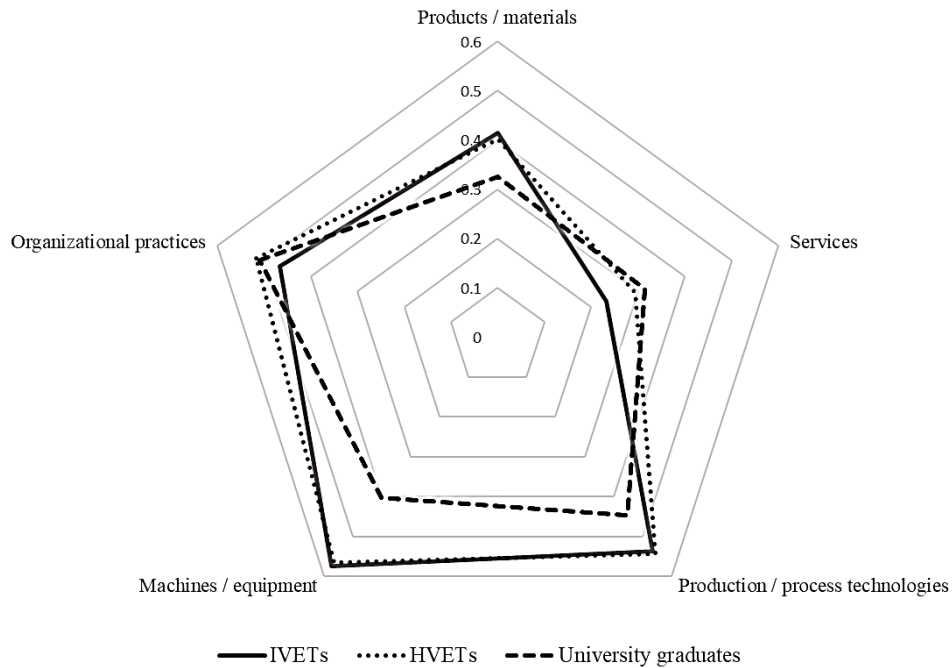
As expected, university graduates are the most likely to be involved in continuous R&D (36.7%), particularly in large firms (see Figure 1 and Table A3). Compared to them, IVETs and HVETs are significantly less involved in continuous R&D, although the gap is smaller for the latter, indicating relatively higher engagement. For the other indicators, the differences between university graduates and VET-qualified employees are generally smaller, suggesting greater innovation participation by IVETs and HVETs in these areas of the invention phase. In some cases, VET-qualified individuals even surpass university graduates: HVETs are 4.2 percentage points more likely to participate in occasional R&D and also more likely to engage in continuous (+2.0 pp) or occasional (+7.0 pp) non-R&D innovation. By contrast, IVETs are less likely to be involved in occasional R&D but more likely to participate in continuous or occasional non-R&D innovation activities (see Figure 1 and Table A3).

These findings provide initial support for H1 and H4: university graduates are heavily engaged in continuous R&D, especially in large firms, while HVETs and IVETs also play roles in invention-phase activities. At that stage of the business innovation process, HVETs emerge as an important actor alongside university graduates, which may indicate some support for H3. IVETs also participate in the invention phase through non-R&D innovation activities, suggesting that Hypothesis 2, which limits their role primarily to the implementation phase, may not fully hold.

4.2. Activities in the implementation phase

Figure 2 and Table A5 in the Appendix present the results for the implementation phase, complementing the invention-phase findings. In line with Hypothesis H2, IVETs are more frequently involved in implementation activities on the shop floor than university graduates, particularly in introducing new production or process technologies (+9.1 pp), new machinery or equipment (+17.2 pp), and new products and materials (+8.9 pp). Conversely, they are less likely to engage in service innovations (−8.1 pp) and new organisational practices (−4.2 pp), likely reflecting their focus on shop-floor tasks with less direct customer contact or organisational management involvement. These patterns suggest a division of labour between IVETs and university graduates in the innovation process. This is particularly evident in large firms (see Table A5), which is consistent with Hypothesis H4. In such firms, IVETs fall significantly behind university graduates in continuous R&D (Section 4.1), yet lead in shop-floor-related implementation activities. This suggests a structured allocation of innovation tasks between R&D departments and operational production areas.

Figure 2. Predicted probabilities for participation of individuals in implementation phase activities, differentiated by professional qualification



Notes: Based on logistic regression results for implementation phase activities (see Table A4 in the appendix).

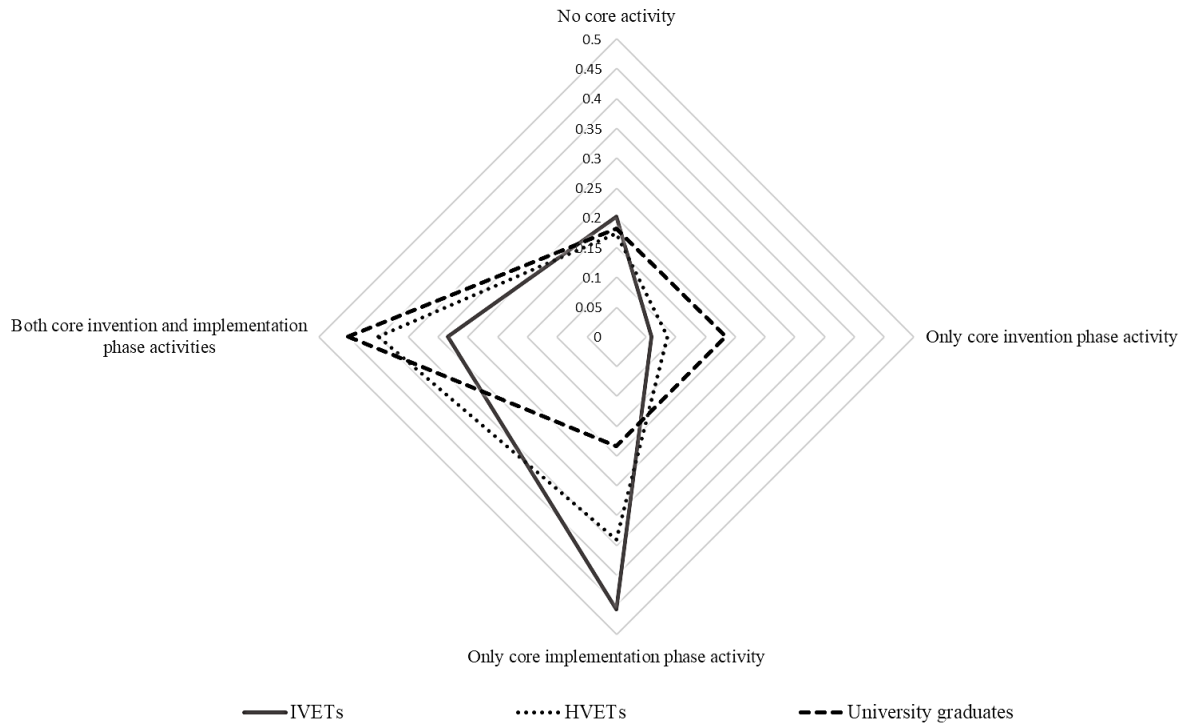
HVETs could potentially act as a bridge between the two other groups. In Figure 2's spider diagram, their dotted line fully encloses the activity ranges of both university graduates and IVETs in the implementation phase, indicating familiarity with both domains. Like IVETs, HVETs are significantly more likely than university graduates to participate in introducing new products, materials, production technologies and machinery, particularly in large firms. However, they are not lagging behind in terms of service innovation or new organisational practices. This combination suggests that HVETs engage in both the practical implementation of ideas and the guidance of IVETs, while also handling complex management and coordination tasks. When considered alongside their relevant involvement in the invention phase (see Section 4.1), these findings regarding the implementation phase suggest that HVETs potentially bridge the gap between the invention and implementation phases in large firms by acting as boundary spanners in the innovation process. This provides some support for hypotheses H3 and H4.

4.3. Combination of core activities at the individual level

The previous analysis examined the average distribution of innovation activities across the invention and implementation phases in manufacturing firms. So far, individual combinations of activities have not been considered. Yet, this is essential for a deeper examination of the four hypotheses. The key questions are whether individuals focus exclusively on one phase (H1, H2), engage in both (H3), and how these patterns vary by firm size (H4). As conceptualized in Section 2 and supported by the preceding empirical results, our focus here is on the combination of core activities at the individual level (see Table 1, for the variable definition) that reflects the interaction between R&D departments and the shop floor.

Figure 3 and Table 2 present the results for these individual-level combinations of core activities. According to these results, university graduates have by far the highest probability of participating exclusively in the invention phase, as measured by participation in occasional or continuous R&D. This finding supports H1. In line with hypothesis H2, IVETs, on the other hand, are most likely to work exclusively in the implementation phase. Both patterns are most pronounced in large firms, which aligns with H4 (see Table 2).

Figure 3. Predicted probabilities for the combination of core activities at the individual level, differentiated by professional qualification



Notes: Based on multinomial logit regression results on the combination of core activities at the individual level (see Table A6 in the appendix).

Table 2: Predictive margin differences for individual combinations of core activities, overall and by firm size category

	No core activity	Only core invention phase activity	Only core implementation phase activity	Both core invention and implementation phase activities
<i>HVETs vs. IVETs</i>	-0.028 *	0.026 ***	-0.116 ***	0.118 ***
#Micro	-0.119 ***	0.052 *	-0.023 n.s.	0.090 **
#Small	-0.010 n.s.	0.035 *	-0.112 ***	0.088 ***
#Medium	-0.038 *	0.030 **	-0.076 ***	0.083 ***
#Large	-0.006 n.s.	0.016 *	-0.160 ***	0.150 ***
<i>University graduates vs. IVETs</i>	-0.019 *	0.125 ***	-0.274 ***	0.169 ***
#Micro	-0.085 *	0.127 ***	-0.159 ***	0.117 ***
#Small	-0.052 *	0.111 ***	-0.208 ***	0.148 ***
#Medium	-0.038 *	0.105 ***	-0.268 ***	0.201 ***
#Large	0.021 n.s.	0.138 ***	-0.329 ***	0.170 ***
<i>University graduates vs. HVETs</i>	0.008	0.099 ***	-0.158 ***	0.051 ***
#Micro	0.033 n.s.	0.075 *	-0.136 ***	0.027 n.s.
#Small	-0.041 n.s.	0.077 **	-0.096 **	0.060 n.s.
#Medium	-0.001 n.s.	0.075 ***	-0.192 ***	0.118 ***
#Large	0.027 n.s.	0.122 ***	-0.168 ***	0.020 n.s.

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, n.s. $p > 0.10$; based on the results of the multinomial logit regression on the combination of core activities at the individual level in Table A6 ($N = 13,486$; controls: other qualification, age, gender, nationality, East Germany, manufacturing industry, year).

Although HVETs are also frequently involved only in the implementation phase, they are significantly more likely than IVETs to participate in both phases of the innovation process – especially in large firms (Figure 3, Table 2). This is consistent with H3 and H4. Remarkably, however, the likelihood of combining both phases is similar for HVETs and university graduates, regardless of firm size. Contrary to H1, many university graduates seem to participate in both phases. This suggests that, in practice, invention and implementation often overlap in R&D work. This pattern remains largely unchanged when the results of a robustness check are considered. For this check, graduates of universities of applied sciences ('FH graduates') are excluded, as they tend to have a more practical orientation than graduates from traditional universities (see Figure A1 in the Appendix). Thus, even without FH graduates, university graduates frequently combine invention and implementation activities. This means that H1 is only partially confirmed. By contrast, for hypothesis H3, the more decisive comparison is between IVETs and HVETs. Figure 3 and Table 2 suggest that HVETs are much more likely than IVETs to combine activities in the invention and implementation phases. This may suggest that they have the potential to play a vital bridge-building role in their firms' innovation processes.

5. Discussion and Conclusion

Our analysis provides empirical evidence of the participation of employees with vocational education and training (VET) qualifications in innovation activities of manufacturing firms, compared with university graduates such as scientists and engineers. It also examines how these participation patterns vary by firm size. We use individual-level data from a broad range of German manufacturing industries to distinguish between three groups of employees: those with initial VET qualifications (IVETs; completed through a dual apprenticeship); those with higher VET qualifications (HVETs; e.g. master craftsmen or technicians); and those with an academic degree from a university or a university of applied sciences (university graduates).

Consistent with previous research, university graduates are strongly involved in the invention phase, particularly through continuous R&D activities, and especially in large firms. However, this engagement is not exclusive; a notable proportion of university graduates also participates in both the invention and implementation phases, suggesting more overlap between them than often assumed. As expected, IVETs are most active in the implementation phase, particularly with regard to shop-floor innovation activities such as introducing new machinery, production technologies, products, and materials. Nevertheless, IVETs also contribute to the invention phase to some extent through non-R&D innovation activities. Overall, however, our findings suggest a relatively clear division of innovation-related tasks between university graduates in R&D departments and IVETs in production.

HVETs occupy a distinctive position in the innovation process. According to our results, they engage in a wide range of activities in the implementation phase and show comparatively high participation in the invention phase. Their likelihood of combining core activities from both phases is similar to that of university graduates and markedly higher than that of IVETs. These findings support the idea that HVETs can act as 'boundary spanners' between R&D units and shop floors, facilitating the transfer and integration of knowledge between different qualification groups of manufacturing firms.

The described division of invention- and implementation-oriented roles between the three qualification groups is most pronounced in large firms, likely due to clearer task allocation and specialization. In smaller firms, roles overlap more, reflecting the broader skill sets required in less specialised settings. As a result, innovation-related division of labour should be less pronounced in SMEs, highlighting the particular importance of VET-qualified employees for innovation in smaller manufacturing firms – a key finding of the two previous studies by Albizu et al. (2017) and Brunet Icart & Rodríguez-Soler (2017).

From policy and management perspectives, these results highlight the importance of viewing vocational and academic qualifications as complementary assets within the innovation system. This involves recognising and promoting the distinctive contributions of various qualification groups, as well as establishing workplace structures that facilitate interactive learning between VET-qualified employees and university graduates, thereby unlocking the innovation potential of a workforce with diverse educational backgrounds.

One limitation of our study is that the available data does not enable us to address potential endogeneity. Therefore, we refrain from making causal claims and use the term 'participation in innovation' rather than 'contribution to innovation'. However, based on the concept of employee-driven innovation (EDI; see Kesting and Ulhøi, 2010; Høyrup, 2010 and 2012), it is plausible that VET employees actively contribute to innovation. According to this approach, if innovations occur in the immediate work environment of "ordinary" employees beyond R&D departments, it is reasonable to assume that they also play an active role in related processes, at least to some degree – particularly if their knowledge and skills are based on specific VET qualifications. Nevertheless, this assumption remains largely theoretical to date and requires further empirical assessment. Another limitation is that our data only allow us to analyse innovation participation at the individual level for the average manufacturing firm. While this provides indications of where qualification groups may interact, it does not provide direct evidence of such

interaction. Studying this would require linked employer–employee datasets or interview data from specific companies.

Against this background, future research should investigate whether the benefits of educational workforce diversity are indeed greater in large firms, or whether similar advantages exist in SMEs. Further work is also needed to examine the presumed boundary-spanning role of HVETs, ideally based on quantitative employer–employee data, qualitative interviews or a combination of both in mixed-method designs. This would improve our understanding of the mechanisms behind their bridge-building function and shed light on how organisational design shapes this function across firms of different sizes. Finally, studies based on panel data would provide a clearer picture of the direct contribution of VET-qualified personnel to innovation –this is therefore another avenue for future research.

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Appendix

Table A1. Descriptive statistics on further variables (N=13,486)

Description		Percent
Age	Age of the respondent in years	44.40
Gender	Gender of the respondent (1=female, 0=male)	31.00
Nationality	Nationality of the respondent (1 = German as mother tongue, 0 = German not as mother tongue)	92.96
East	Federal state of the respondent (1=East Germany, 0 West Germany)	15.82
Manufacturing industry (WZ 2003)		
Food	1 if Food products and beverage	9.02
Tobacco	1 if Tobacco products	0.13
Textiles	1 if Textiles	1.94
Wearing	1 if Wearing apparel; dressing and dyeing of fur	0.84
Leather	1 if Leather and leather products	0.19
Wood	1 if Wood and wood products	1.93
Paper	1 if Pulp, paper and paper products; publishing and printing	1.57
Printing	1 if Publishing, printing and reproduction of recorded media	5.39
Coke	1 if Coke, refined petroleum products and nuclear fuel	0.22
Chemicals	1 if Chemicals, chemical products and man-made fibres	10.33
Rubber	1 if Rubber and plastic products	2.22
Glass	1 if Other non-metallic mineral products	1.91
Basic metal	1 if Basic metals	2.60
Fabricated metal	1 if Fabricated metal products, except machinery and equipment	12.20
Machinery	1 if Machinery and equipment	13.38
Computers	1 if Office machinery and computers	0.30
Electronics	1 if Electrical machinery and apparatus	8.65
Communication	1 if Radio, television and communication equipment and apparatus	2.48
Optics	1 if Medical, precision and optical instruments, watches, clocks	4.18
Automobile	1 if Motor vehicles, trailers and semi-trailers	15.95
Other transport	1 if other transport equipment	2.08
Furniture	1 if Furniture	2.03
Recycling	1 if Recycling	0.46
Survey year		
2006	1 if survey year is 2006	35.29
2012	1 if survey year is 2012	34.09
2018	1 if survey year is 2018	30.62

Table A2. Multinomial logit regression on invention phase activities (dep. variable: activities in the invention phase; base outcome: no activity)

	Occasional innovator without R&D	Continuous innovator without R&D	Occasional R&D	Continuous R&D
No profess. qualification (Ref.)				
Other qualification	0.532 (0.362)	0.838* (0.491)	1.082*** (0.370)	1.739*** (0.404)
IVETs	0.491* (0.274)	0.677* (0.396)	0.542* (0.299)	-0.112 (0.359)
HVETs	0.766** (0.371)	1.290*** (0.483)	1.242*** (0.377)	1.155*** (0.427)
University graduates	1.275*** (0.413)	1.510*** (0.534)	1.744*** (0.428)	2.275*** (0.461)
Micro firms (Ref.)				
Small firms	-0.038 (0.318)	0.206 (0.450)	-0.433 (0.365)	-0.891** (0.451)
Medium firms	-0.147 (0.301)	0.282 (0.424)	-0.617* (0.340)	-1.407*** (0.451)
Large firms	0.138 (0.289)	0.211 (0.417)	-0.369 (0.323)	-0.970** (0.400)
Small firms#Other qualification	0.434 (0.459)	-0.202 (0.618)	0.421 (0.488)	0.115 (0.554)
Small firms#IVETs	0.102 (0.340)	-0.452 (0.480)	0.198 (0.387)	0.689 (0.482)
Small firms#HVETs	0.025 (0.460)	-1.000 (0.611)	-0.008 (0.484)	0.407 (0.565)
Small firms#University grad.	-0.192 (0.528)	-0.678 (0.683)	-0.014 (0.554)	0.535 (0.606)
Medium firms#Other qualific.	0.262 (0.426)	-0.648 (0.575)	0.345 (0.445)	0.504 (0.530)
Medium firms #IVETs	0.078 (0.323)	-0.472 (0.451)	0.278 (0.362)	1.038** (0.479)
Medium firms #HVETs	0.301 (0.443)	-0.178 (0.560)	0.453 (0.457)	0.900 (0.559)
Medium firms #University grad.	0.237 (0.496)	-0.383 (0.629)	0.726 (0.517)	1.321** (0.591)
Large firms#Other qualification	0.264 (0.409)	0.438 (0.545)	0.444 (0.424)	0.791* (0.477)
Large firms #IVETs	-0.024 (0.309)	-0.162 (0.440)	0.043 (0.343)	0.566 (0.427)
Large firms #HVETs	0.158 (0.415)	-0.259 (0.537)	0.348 (0.427)	0.614 (0.499)
Large firms #University grad.	-0.275 (0.457)	0.119 (0.584)	0.158 (0.476)	0.903* (0.527)
Age	-0.007*** (0.003)	-0.015*** (0.003)	-0.023*** (0.003)	-0.022*** (0.003)
Gender	0.087 (0.056)	-0.137* (0.071)	-0.991*** (0.063)	-1.148*** (0.077)
Nationality	0.359*** (0.102)	0.416*** (0.130)	0.475*** (0.108)	0.385*** (0.119)
East	-0.341*** (0.068)	-0.385*** (0.089)	-0.421*** (0.071)	-0.696*** (0.087)
Manufacturing industries	Yes	Yes	Yes	Yes

Table A2. (continued)

2006 (Ref.)				
2012	0.055 (0.063)	0.135* (0.080)	0.079 (0.066)	0.180** (0.076)
2018	0.089 (0.068)	0.270*** (0.084)	0.159** (0.070)	0.250*** (0.079)
Constant	-0.570* (0.297)	-1.405*** (0.428)	0.189 (0.323)	-0.574 (0.390)

$N = 13,486$

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; regression coefficients are shown; robust standard errors in parentheses.

Table A3: Predictive margin differences for invention phase activities, overall and by firm size category

	No activity	Occasional innovator without R&D	Continuous innovator without R&D	Occasional R&D	Continuous R&D
<i>HVETS vs. IVETs</i>	-0.097 ***	-0.046 ***	-0.002	0.066 ***	0.078 ***
#Micro	-0.086 ***	-0.063 *	0.006 n.s.	0.031 n.s.	0.111 ***
#Small	-0.063 **	-0.038 n.s.	-0.024 n.s.	0.033 n.s.	0.091 ***
#Medium	-0.113 ***	-0.035 n.s.	0.035 *	0.057 **	0.057 ***
#Large	-0.103 ***	-0.049 *	-0.015 n.s.	0.089 ***	0.078 ***
<i>University graduates vs. IVETs</i>	-0.154 ***	-0.116 ***	-0.022 ***	0.024 **	0.268 ***
#Micro	-0.140 ***	-0.077 **	-0.032 n.s.	-0.005 n.s.	0.254 ***
#Small	-0.132 ***	-0.102 ***	-0.027 n.s.	0.001 n.s.	0.260 ***
#Medium	-0.178 ***	-0.088 ***	-0.039 **	0.065 **	0.240 ***
#Large	-0.151 ***	-0.146 ***	-0.007 n.s.	0.016 n.s.	0.288 ***
<i>University graduates vs. HVETs</i>	-0.057 ***	-0.070 ***	-0.020 *	-0.042 ***	0.190 ***
#Micro	-0.053 *	-0.014	-0.038 n.s.	-0.037 n.s.	0.142 ***
#Small	-0.070 **	-0.064 *	-0.003 n.s.	-0.032 n.s.	0.169 ***
#Medium	-0.064 ***	-0.053 *	-0.074 ***	0.008 n.s.	0.183 ***
#Large	-0.048 ***	-0.097 ***	0.008 n.s.	-0.073 ***	0.210 ***

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, n.s. $p > 0.10$; based on the results of the multinomial logit regression on invention phase activities in Table A2 ($N = 13,486$; controls: other qualification, age, gender, nationality, East Germany, manufacturing industry, year).

Table A4. Logistic regression on implementation phase activities

	Products / materials	Services	Production / process technologies	Machines / equipment	Organiza- tional practices
No profess. qualification (Ref.)					
Other qualification	0.530* (0.308)	0.381 (0.291)	0.357 (0.265)	0.142 (0.263)	0.204 (0.285)
IVETs	0.582** (0.272)	-0.049 (0.259)	-0.032 (0.232)	0.255 (0.226)	0.005 (0.245)
HVETs	0.526* (0.305)	0.613** (0.287)	0.250 (0.266)	0.662** (0.261)	-0.015 (0.286)
University graduates	0.396 (0.315)	0.540* (0.292)	-0.053 (0.278)	-0.171 (0.275)	0.146 (0.289)
Micro firms (Ref.)					
Small firms	1.067*** (0.303)	-0.106 (0.312)	0.321 (0.270)	0.515* (0.265)	0.612** (0.279)
Medium firms	0.973*** (0.292)	-0.066 (0.293)	0.818*** (0.252)	0.861*** (0.254)	0.705*** (0.264)
Large firms	1.219*** (0.282)	0.516* (0.269)	1.575*** (0.245)	1.380*** (0.245)	1.173*** (0.253)
Small firms#Other qualification	-0.771** (0.373)	0.173 (0.382)	-0.206 (0.341)	-0.052 (0.336)	-0.160 (0.354)
Small firms#IVETs	-0.772** (0.318)	0.295 (0.332)	0.289 (0.288)	-0.015 (0.281)	-0.058 (0.297)
Small firms#HVETs	-0.674* (0.366)	-0.103 (0.375)	-0.028 (0.336)	-0.597* (0.330)	0.067 (0.352)
Small firms#University grad.	-0.936** (0.385)	0.025 (0.387)	0.398 (0.353)	-0.158 (0.351)	-0.247 (0.362)
Medium firms#Other qualific.	-0.423 (0.351)	0.025 (0.354)	-0.137 (0.311)	-0.244 (0.313)	0.488 (0.329)
Medium firms #IVETs	-0.501 (0.307)	0.253 (0.312)	0.287 (0.269)	-0.180 (0.269)	0.250 (0.282)
Medium firms #HVETs	-0.446 (0.349)	-0.106 (0.351)	0.081 (0.314)	-0.772** (0.313)	0.653** (0.331)
Medium firms #University grad.	-0.603* (0.358)	0.210 (0.352)	-0.009 (0.323)	-0.375 (0.324)	0.262 (0.333)
Large firms#Other qualification	-0.900*** (0.335)	-0.324 (0.323)	-0.847*** (0.296)	-1.049*** (0.297)	0.159 (0.313)
Large firms #IVETs	-0.614** (0.296)	-0.188 (0.288)	-0.063 (0.261)	-0.555** (0.259)	0.295 (0.270)
Large firms #HVETs	-0.667** (0.332)	-0.570* (0.320)	-0.365 (0.298)	-0.975*** (0.297)	0.524* (0.314)
Large firms #University grad.	-0.934*** (0.340)	-0.427 (0.322)	-0.705** (0.307)	-1.053*** (0.306)	0.446 (0.314)
Age	-0.006*** (0.002)	0.004** (0.002)	-0.003* (0.002)	-0.007*** (0.002)	-0.002 (0.002)
Gender	-0.498*** (0.042)	-0.139*** (0.047)	-0.512*** (0.041)	-0.796*** (0.041)	-0.090** (0.041)
Nationality	-0.346*** (0.071)	-0.237*** (0.078)	-0.150** (0.072)	-0.218*** (0.074)	-0.016 (0.072)
East	0.025 (0.051)	-0.128** (0.057)	-0.037 (0.050)	0.144*** (0.051)	-0.304*** (0.050)
Manufacturing industries	Yes	Yes	Yes	Yes	Yes

Table A4. (continued)

2006 (Ref.)					
2012	-0.060 (0.044)	-0.199*** (0.049)	-0.117*** (0.044)	-0.181*** (0.044)	-0.196*** (0.044)
2018	-0.017 (0.046)	-0.236*** (0.051)	-0.177*** (0.046)	-0.147*** (0.046)	-0.126*** (0.046)
Constant	-0.556** (0.282)	-1.228*** (0.271)	-0.466* (0.244)	0.403* (0.241)	-1.093*** (0.257)
<i>N</i>	13,304	13,252	13,337	13,386	13,430

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; regression coefficients are shown; robust standard errors in parentheses.

Table A5: Predictive margin differences for implementation phase activities, overall and by firm size category

	Products / materials	Services	Production / process technologies	Machines / equipment	Organizational practices
<i>HVETS vs. IVETs</i>	-0.012 n.s.	0.062 ***	0.007 n.s.	-0.009 n.s.	0.050 ***
#Micro	-0.012 n.s.	0.122 ***	0.059 n.s.	0.097 **	-0.004 n.s.
#Small	0.010 n.s.	0.049 *	-0.008 n.s.	-0.041 n.s.	0.024 n.s.
#Medium	-0.000 n.s.	0.056 **	0.018 n.s.	-0.043 n.s.	0.094 ***
#Large	-0.026 n.s.	0.055 ***	-0.005 n.s.	-0.003 n.s.	0.050 **
<i>University graduates vs. IVETs</i>	-0.089 ***	0.081 ***	-0.091 ***	-0.172 ***	0.042 ***
#Micro	-0.038 n.s.	0.107 ***	-0.004 n.s.	-0.095 **	0.026 n.s.
#Small	-0.076 **	0.060 *	0.021 n.s.	-0.134 ***	-0.011 n.s.
#Medium	-0.066 **	0.107 ***	-0.077 ***	-0.147 ***	0.038 n.s.
#Large	-0.117 ***	0.070 ***	-0.158 ***	-0.217 ***	0.069 ***
<i>University graduates vs. HVETs</i>	-0.077 ***	0.020 n.s.	-0.098 ***	-0.163 ***	-0.008 n.s.
#Micro	-0.026 n.s.	-0.016 n.s.	-0.063 n.s.	-0.192 ***	0.030 n.s.
#Small	-0.086 *	0.011 n.s.	0.029 n.s.	-0.093 **	-0.035 n.s.
#Medium	-0.066 *	0.051 n.s.	-0.096 ***	-0.104 ***	-0.057 n.s.
#Large	-0.090 ***	0.015 n.s.	-0.154 ***	-0.213 ***	0.0190 n.s.
<i>N</i>	13,304	13,252	13,337	13,386	13,430

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, n.s. $p > 0.10$; based on the results of the logistic regressions on implementation phase activities in Table A4 (controls: other qualification, age, gender, nationality, East Germany, manufacturing industry, year).

Table A6. Multinomial logit regression on the combination of core activities at the individual level (dep. variable: combination of core activities; base outcome: no core activity)

	Only core invention phase activity	Only core implementation phase activity	Both core invention and implementation phase activities
No professional qualification (Ref.)			
Other qualification	0.874** (0.384)	0.136 (0.341)	1.233*** (0.352)
IVETs	-0.097 (0.337)	0.249 (0.267)	0.261 (0.310)
HVETs	0.807** (0.404)	0.711** (0.342)	1.134*** (0.371)
University graduates	1.001*** (0.385)	-0.175 (0.368)	1.053*** (0.367)
Micro firms (Ref.)			
Small firms	-1.009* (0.515)	0.772** (0.309)	0.138 (0.373)
Medium firms	-0.319 (0.419)	1.205*** (0.298)	-0.026 (0.369)
Large firms	-0.934* (0.481)	1.736*** (0.296)	0.894** (0.348)
Small firms#Other qualification	0.720 (0.613)	0.211 (0.432)	-0.007 (0.465)
Small firms#IVETs	0.719 (0.542)	-0.099 (0.329)	0.215 (0.394)
Small firms#HVETs	0.292 (0.618)	-0.810* (0.427)	-0.295 (0.471)
Small firms#University graduates	0.901 (0.607)	-0.071 (0.469)	0.206 (0.478)
Medium firms#Other qualification	-0.220 (0.516)	-0.267 (0.406)	0.208 (0.443)
Medium firms #IVETs	-0.183 (0.451)	-0.309 (0.318)	0.530 (0.388)
Medium firms #HVETs	-0.377 (0.540)	-0.720* (0.413)	0.169 (0.463)
Medium firms #University graduates	0.143 (0.508)	-0.514 (0.438)	0.595 (0.456)
Large firms#Other qualification	0.621 (0.543)	-0.999** (0.390)	-0.725* (0.411)
Large firms #IVETs	0.394 (0.503)	-0.560* (0.313)	-0.296 (0.366)
Large firms #HVETs	-0.104 (0.569)	-1.337*** (0.392)	-0.634 (0.429)
Large firms #University graduates	0.700 (0.540)	-1.255*** (0.412)	-0.636 (0.422)
Age	-0.014*** (0.003)	-0.005** (0.002)	-0.021*** (0.003)
Gender	-1.102*** (0.082)	-0.770*** (0.053)	-1.680*** (0.060)
Nationality	0.014 (0.145)	-0.244** (0.103)	0.015 (0.109)
East	-0.201** (0.101)	0.110 (0.067)	-0.207*** (0.073)
Manufacturing industries	Yes	Yes	Yes

Table A6. (continued)

2006 (Ref.)			
2012	0.170*	-0.133**	-0.081
	(0.090)	(0.060)	(0.064)
2018	0.179*	-0.178***	-0.083
	(0.092)	(0.065)	(0.068)
Constant	-0.425	0.601**	0.863***
	(0.396)	(0.295)	(0.335)

$N = 13,486$

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; regression coefficients are shown; robust standard errors in parentheses.

Figure A1. Predicted probabilities for the combination of core activities at the individual level, differentiated by professional qualification (robustness test without graduates from universities of applied sciences in the 'university graduates' group)

