Institut für Wirtschaftsforschung Halle

Halle Institute for Economic Research

Does Qualification Drive Innovation? A Microeconometric Analysis Using Linked-employer-employee Data

Bianca Brandenburg, Jutta Günther, Lutz Schneider

September 2007

No. 10

IWH-Diskussionspapiere

IWH-Discussion Papers

Does Qualification Drive Innovation?
A Microeconometric Analysis
Using Linked-employer-employee Data

Bianca Brandenburg, Jutta Günther, Lutz Schneider

September 2007 No. 10

Authors: *Bianca Brandenburg*
Federal Ministry of Finance (BMF), Germany
Bianca.Brandenburg@bmf.bund.de

Dr. Jutta Günther
Halle Institute for Economic Research (IWH), Germany
Jutta.Guenther@iwh-halle.de

Lutz Schneider
Halle Institute for Economic Research (IWH), Germany
Lutz.Schneider@iwh-halle.de

The responsibility for discussion papers lies solely with the individual authors. The views expressed herein do not necessarily represent those of the IWH. The papers represent preliminary work and are circulated to encourage discussion with the author. Citation of the discussion papers should account for their provisional character; a revised version may be available directly from the author. Comments and suggestions on the methods and results presented are well-come.

IWH-Discussion Papers are indexed in RePEc-Econpapers and in ECONIS.

This research has been partially financed by the EU Commission, in Framework Program 6, Priority 7 on "Citizens and Governance in a knowledge based society", contract no. CIT5-028519. The authors are solely responsible for the contents which might not represent the opinion of the Community. The Community is not responsible for any use that might be made of data appearing in this publication.

Herausgeber:
INSTITUT FÜR WIRTSCHAFTSFORSCHUNG HALLE – IWH
Prof. Dr. Ulrich Blum (Präsident), Dr. Hubert Gabrisch (Forschungsdirektor)
Das IWH ist Mitglied der Leibniz-Gemeinschaft

Address: Kleine Märkerstraße 8, 06108 Halle (Saale)
PO box: Postfach 11 03 61, 06017 Halle (Saale)
Phone: (0345) 77 53-60
Fax: (0345) 77 53-8 20
Internet: http://www.iwh-halle.de

Does Qualification Drive Innovation? A Microeconometric Analysis Using Linked-employer-employee Data

Abstract

Degree-level science and engineering skills as well as management and leadership skills are often referred to as a source of innovative activities within companies. Broken down by sectoral innovation patterns, this article examines the role of formal education and actual occupation for product innovation performance in manufacturing firms within a probit model. It uses unique micro data for Germany (LIAB) that contain detailed information about innovative activities and the qualification of employees. We find significant differences of the human capital endowment between sectors differentiated according to the Pavitt classification. Sectors with a high share of highly skilled employees engage in product innovation above average (specialized suppliers and science based industries). According to our hitherto estimation results, within these sectors the share of highly skilled employees does not, however, substantially increase the probability to be an innovative firm.

Key words: innovation, human capital, qualification, sectoral innovation system

JEL classification: O31, J 24

Zusammenfassung

Natur- und ingenieurwissenschaftliche Fähigkeiten sowie Management- und Führungskompetenzen werden häufig als Quelle von betrieblichen Innovationsaktivitäten betrachetet. Der vorliegende Artikel untersucht die Rolle von Humankapital im Sinne des formalen Bildungsabschlusses und des tatsächlich ausgeübten Berufes für die betriebliche Innovationstätigkeit im Rahmen eines Probit-Ansatzes, wobei zwischen sektoralen Innovationsregimen unterschieden wird. Die Analyse basiert auf einem Mikrodatensatz deutscher Betriebe (LIAB), welcher detailierte Informationen über die Innovationsaktivitäten und die Qualifikation der Beschäftigten enthält. Es zeigen sich signifikante Unterschiede der Humankapitalausstattung zwischen Sektoren, welche nach der Pavitt-Klassifikation unterschieden wurden. Sektoren mit einem hohen Anteil hochqualifizierter Beschäftigter sind überdurchschnittlich oft unter den Produktinnovatoren zu finden (spezialisierte Zulieferer und wissenschaftsbezogene Branchen). Indes lassen die realisierten Regressionen keine signifikanten Effekte der Beschäftigtenqualifikation auf die Innovationstätigkeit innerhalb dieser Branchen erkennen.

Schlüsselwörter: Innovation, Humankapital, Qualifikation, sektorale Innovationssysteme

Does Qualification Drive Innovation? A Microeconometric Analysis Using Linked-employer-employee Data

1 Introduction[1]

Education, R&D and innovation rank very high in today's policy agendas. Frequently citied in this context is the Lisbon strategy of the EU. Although the originally ambiguous goals have been revised recently (European Commission 2005), the agenda is still recognized as a political milestone in support of the knowledge based economy. Complementary to this, Germany, like many other EU countries, launched a national master plan, too. The "High-tech Strategy for Germany" (BMBF 2006a) emphasises the need to focus on the creation of new knowledge and particularly on the translation of new knowledge and inventions into marketable products.

The need for action is obvious. On the one hand, we face an ongoing structural change towards a knowledge based society (Heidenreich 2003). On the other hand, Germany faces decreasing numbers of university students (Statistisches Bundesamt 2005), a demographic change towards an aging society (Statistisches Bundesamt 2006), and a lack of qualified workers (Reinberg and Hummel 2004, BMBF 2006b, pp. 61 sqq.). As shown by innovation survey data, the lack of qualified employees as a hampering factor for innovation is even stronger in Germany compared to most other EU countries (Lucking 2004, p. 18).

In this paper we take a closer look on the relationship between human capital and innovation. This relationship is not one-dimensional. Concerning the heterogeneity of labour, new technologies often require organizational changes and different qualifications. A wide range of literature addresses the skill biased technological change and empirical findings indicate that innovation is generally associated with an increase in high-skilled and a decline in low-skilled employment (e.g. Pianta 2005, pp. 575 sqq.; Blechinger and Pfeiffer 1999).

On the other hand, we can regard human capital as a central determinant or input of innovation. This paper explicitly considers the impact of the human capital endowment in terms of qualification on product innovation processes in manufacturing firms. From a

1 The paper has been presented at the "Workshop on Economics of Knowledge and Innovation" on July 11, 2007 at the Halle Institute for Economic Research (IWH). Thanks go to the participants of the workshop who gave us helpful comments and recommendations. Furthermore the authors thank the Institute for Employment Research Nuernberg (*Institut für Arbeitsmarkt- und Berufsforschung, IAB*) for the provision of data.

scientific point of view the role of human capital as an important input for innovation is well recognized and documented in the new growth theory. Nevertheless, current empirical studies explicitly investigating the relationship between human capital and firms' innovation performance are rare.

A recent study of Dakhli and De Clercq (2003) finds evidence for the importance of human capital as a determinant of innovation. The results are based on a cross-country analysis, where innovation is proxied through patents, R&D expenditure, and high-tech exports. But direct innovation measures and firm level data should be preferred in our context. Rammer et al. (2005, pp. 214 sqq.) use innovation survey data for Germany and provide evidence for the importance of human capital as a determinant of firms' overall innovation activity. When looking at particular types of product innovation, however, the coefficient turns insignificant or even significantly negative. An empirical study from Günther and Gebhardt (2005) provides similar results. Using micro data for establishments (local business units) in East Germany they find no significant impact of human capital on establishments' innovation activity. In both analyses, human capital is measured as the share of employees with a higher education degree.

To sum up, existing studies show different results, and they use education degrees as a measure for human capital. In this paper, we make use of alternative micro data for Germany – a linked employer-employee data set – which allows us to consider the actual occupation of employees instead of just the formal qualification and the duration of employment. Furthermore, based on the idea of sectoral innovation systems, we consider branch differences within manufacturing industry, too. The following chapter presents the theoretical considerations followed by the introduction of the econometric model and the data in Chapter 3. Finally, estimation results are presented (Chapter 4) and conclusions drawn (Chapter 5).

2 Innovation in Skill Related and Sectoral Perspective

2.1 Human Capital and Innovation

New Growth Theory

The technological progress in common growth models often refers to innovation as an important source of economic growth. Different from traditional growth theory, models of endogenous growth relate the human capital stock to a country's ability to innovate and catching-up with more advanced economies and specify technological change or the growth of total factor productivity as a function of human capital. Thereby investments in human capital and R&D lead to technological change (innovation) and increase the productivity of labour and capital at firm level constantly (Romer 1986; Aghion and Howitt 1998). Due to the public good character of technology, spillovers occur between firms, and the economy faces increasing returns to investment and thus long run growth (Grossman and Helpman 1997). There are various specifications in new growth models that particularly stress the role of human capital (Barro and Sala-i-Martin 1998, pp. 200 sqq.), but the wide spectrum would go beyond the scope and the need of this paper. What remains important for the purpose of this paper is the fact that the new growth theory underlines the importance of qualified employees as an input for the R&D sector where new knowledge is created and subsequently introduced in the form of new products etc. Basically, one can assume that an increasing supply of human capital leads to a better performance of innovation.

While endogenous growth theory takes a macro perspective, we might also assume that the central message of new growth theory – human capital as an important determinant of innovation – applies at the firm level, too. However, the mechanisms through which highly qualified people contribute to innovation remain an unexplored topic in economic theory. In search for a stronger theoretical backing at the firm level, we additionally consult theoretical approaches concerning the interdisciplinary field of innovation studies.[2]

Into the Black Box: Innovation Studies

Contributions, usually assigned to the area of innovation studies or systemic innovation theory take a holistic view and contribute to a better understanding of the nature of the innovation process as such.[3]

The traditional model of science-push (Bush 1945) stressed the importance of R&D as well as science and engineering skills in the sense of a small elite group for innovation processes. Later on, this so-called linear model has been extended by the perspective

2 For an insightful discussion of "innovation studies" as a discipline, see *Fagerberg and Verspagen* (2006).

3 For an overview, see *Fagerberg et al.* (2005).

that innovation is an interactive processes that largely involves inter-personal as well as inter-organizational learning too (e.g. Kline and Rosenberg 1986).

As regards human capital more specifically, Nelson and Phelps (1966) documented in a simple growth model that better educated people fulfil regular activities more effectively, and that they are more competent in the use and exploitation of new technologies. The latter aspect has been proven empirically by showing that high-educated farmers introduce new technologies quicker and with better results than average. Similar findings have been documented by Schultz (1975), who refers to the exploitation competence as an ‘entrepreneurial’ capability.

Lundvall (2007) picks up this topic and develops it further in the context of the ‘learning economy’ (Lundvall and Johnson 1994). He states that there are two ways by which higher education impacts on innovation: On the one hand, higher education graduates can operate as basic innovators for instance by inventing and developing new technologies. On the other hand, they might serve as second stage innovators, who rather exploit the technological progress and assure the ‘equilibrium’ between technological change and daily business. According to this differentiation, he concludes that engineers and scientists are particularly active as basic innovators while people with a management and social sciences degree are important as second stage innovators.

Human capital covers knowledge, embodied skills, and expertise that people bring into organizations and society. One important component of human capital is the formal qualification, and as indicated above, especially tertiary education is viewed as a crucial determinant for innovative activity. Accordingly, we formulate our first hypothesis as follows.

Hypothesis 1: The higher the human capital endowment in terms of engineers, scientist, and managers, the higher the company’s innovation output.

2.2 Sectoral Innovation Regimes

In the tradition of evolutionary theory, the theoretical concept of ‘sectoral innovation system’ starts from the idea that firms are not homogenous regarding their innovation processes. Instead, sectors largely differ with respect to their innovation processes. Malerba (2005) explains this along three dimensions: i.e. knowledge and technological domain, actors and networks and institutions.

From the literature, we know different approaches to make distinctions among sectors regarding their technological or innovation regime.[4]

The simplest classification, frequently used in international comparative studies, is the one made by the OECD, developed by Hatzichronoglou (1997). According to R&D in-

4 For a recent overview of industry classifications in general, see e.g. *Peneder* (2003).

tensity one can distinguish high-technology, medium-high-technology, medium-low-technology, low-technology industries.

An expanded industry classification, frequently used in empirical innovation studies, was introduced by Pavitt (1984). In his view, several sources matter for innovation, not only own R&D but also aspects like supplier-customer relations, learning-by-doing or learning-by-interacting, etc. Based on a very extensive data set on innovation for the UK, he distinguishes four categories according to different innovation patterns, which have their own requirements for skill-sets.[5]

(1) Science-based industries are characterized by much organized R&D with a strong link to university or other publicly funded basic research. These industries require high-level science and engineering skills, such as in chemical industry or electronics.

(2) Specialized suppliers are characterized by a close relationship with frequent users. Firms in this category strongly focus on product innovations and require skills of interactive learning as well as the capacity to develop highly client specific solutions and vocational, practical development skills. A typical example for specialized suppliers is machinery.

(3) Scale intensive industries are production intensive companies with rather simple production, and often with mass products. Innovation is mostly process oriented. R&D activities predominantly serve internal purposes. Economies of scale require scientific managers with cross-functional skills, specialists in product design, development skills as well as a qualified workforce that is able to adapt new technologies (e.g. transport equipment, steel industry).

(4) Supplier dominated industries tend to be oriented towards process innovation. Operators in this category are mostly defined in terms of their professional skills, design, brand and advertising. Technological innovations, however, mainly come from outside the companies. In-house R&D and engineering capabilities are considered to be weak (e.g. textile industry).

According to Pavitt (1984), the science-based industries and the specialized suppliers serve the rest of the economy with new technology. Thereby, scale intensive industries mostly take over and adapt external technology while supplier dominated industries hardly fulfil own development activities. With respect to human capital, we formulate the following hypothesis.

Hypothesis 2: The higher the original innovation activity of a sector, the stronger the importance of a highly qualified workforce.

5 The assignment of industries (three digit level) to the four Pavitt categories based on International Standard Industrial Classification of All Economic Activities, Revision 3 (1990) is shown in Appendix (see Table 4).

3 Model and Data

3.1 Econometric Model

Besides bivariate descriptive analysis, the hypotheses are tested on the basis of a micro-econometric probit model, since the firm's innovation activity as dependent variable is measured by a binary variable. The innovation variable is regressed on variables representing the firm's human capital endowment in terms of qualification. In order to avoid regression biases due to the problem of omitted variables, almost every central impact on the innovation behavior of the firm – additional to the primarily interesting level of qualification – has to be included in the estimation. In accordance to the empirical literature focusing on determinants of innovation activity the following exogenous variables are taken into account:[6]

Firm size: The size of an enterprise is assumed to facilitate the innovation activity due to more favorable conditions to finance innovations, the availability of real and human capital resources, and the exploitation of scale effects.[7]

R&D activities: According to the 'science push model' of innovation, R&D is a central source of innovation. Although this one-dimensional perspective has been extended in the meantime, we still have to assume that enterprises should be particularly innovative if they employ resources for the development of new products.

Job tenure & experience: On the one hand, a longer work experience within the same firm should drive innovation, since experienced employees have learned from past innovation problems. Therefore, the risk of innovation failure is reduced. On the other hand, experience might cause technological inertia limiting the scope and intensity of innovations. Hence, from a theoretical point of view, the impact of experience on innovation output is quite ambiguous and the empirical literature has largely neglect this topic so far.

Further training: This variable tells whether the firm invests in further education of the employees. In the sense of life-long-learning, such activities add to the knowledge and capabilities of the workforce and are associated with a positive impact on the innovation behavior.

---

6 A discussion of the variables selected here can be found in *Günther and Gebhardt* (2006); *Gottschalk and Janz* (2003); *Rammer et al*. (2005).

7 This assumption originally dates back to Schumpeter, the pioneer of innovation research. Recent empirical studies indicate that a linear relationship between size and innovation cannot clearly be confirmed any longer (*Gottschalk and Janz* 2003).

Profitability: The financing of innovation activities predominantly comes from internal resources of the firm since banks are usually reluctant to provide capital for risky projects like innovation. Accordingly, a profitable firm will be more likely to generate the monetary resources needed for innovations.

Export intensity: Firms selling their products on foreign markets are subject to global competition forces – a survival under strong competition should require persistent innovation efforts.

Age of the firm: A high age of a firm might indicate the ability to meet market challenges sufficiently, thus ample adaptation capacities could be expected. From this point of view the age of a firm should be positively correlated to its innovation activities. However, one reason for the emergence of enterprises might refer to the fact that existing (older) firms will resist radical types of innovations – e.g. due to path dependencies. Therefore, the impact of the age of the firm is not clear cut.

Equipment: A sufficient technological standard is a precondition for the feasibility of elaborate innovation types. Moreover, the technical equipment complements the absorptive abilities of an enterprise. Hence, a high level of technology should promote the innovation propensity of firms.

Foreign ownership: In order to control for different access to non-market knowledge flows, a dummy variable measuring a majority foreign ownership is implemented. Due to an easier import of advanced technology from the multinational enterprise group, a foreign owned firm should face advantages in innovation processes.

East-location: Due to regional distinctions resulting from the transition period, a dummy is included controlling for an unexplained East-effect, thereby expecting a lower innovativeness of firms located in the Eastern part of Germany.

Thus, the estimation equation has the following general form:

$$y_i^* = \alpha + \beta HK_i + \gamma' \mathrm{X}_i + e_i$$

$$\text{with} \quad y_i = \begin{cases} 1 \text{ if } y_i^* > 0 \\ 0 \text{ if } y_i^* \leq 0 \end{cases} \quad \text{and } e \sim \mathrm{N}(0,1)$$

Where y_i denotes our binary outcome, which takes the value of 1 if firm i is active in product innovation, and y^* is a latent variable. *HK* is our qualification variable, denoting the share of high-qualified employees respectively in terms of formal education or occupational characteristics alternatively. γ denotes a vector of coefficients for the above described exogenous control variables in X_i, α represents the constant, and e denotes the error term. The estimations are limited to the manufacturing sector (without construction) and to firms with at least 10 employees.[8] The model is estimated for the entire sample and separately for each of the four sub-samples according to the Pavitt categories.

3.2 Data

The analysis is carried out on the basis of the linked-employer-employee dataset (LIAB), provided by the Institut für Arbeitsmarkt- und Berufsforschung Nuremberg, Germany.[9] The dataset contains firm-level data from the IAB-Betriebspanel, an annual panel survey of about 15,000 German firms, and individual data of the employees working in the panel firms. The individual statistics covers all workers, which are in the scope of the national social insurance system. For the topic of this paper, the LIAB dataset is an appropriate data base since the firm-level data about innovation activity and other relevant firm characteristics can be combined with information on the qualification level of the firms' employees. Hence, the question how the qualification of a firm's workforce affects its innovation behavior can appropriately be addressed. An advantage of the data set consists in the rich information about the qualification structure. Qualification can be measured not only in terms of formal education (degrees), but also in terms of the actual occupational status. So, the data precisely allow for detecting the actual qualification level within a firm.

The dependent variable stemming from the panel survey is binary coded.[10] A value of 1 is assigned if the firm is engaged in product innovation. Three categories of product innovation are distinguished in the data set:

i) Improvement of an existing product (*improvement*)
ii) Introduction of a product new to the firm – extension of the product range (*new product*)
iii) Creation of a market novelty (*market novelty*)

In addition, the aggregate variable *product innovation* is set to 1 if at least one of the three types of product innovation was realized.

The collection of innovation data through the IAB-Betriebspanel largely corresponds to the international standards of innovation surveys provided in the 'Oslo Manual' (OECD

8 Innovations in the other sectors – in particular regarding the service industries – are difficult to identify and factors driving innovation cannot be easily determined (*Hempel* 2003). Under this conditions, an estimation runs the risk to neglect substantial impact of innovation behavior, the estimation coefficients will therefore be biased.

9 For a description of the data set see *Alda* (2005) and *Alda and Herrlinger* (2005).

10 A detailed description of endogenous and exogenous variables is given in the Appendix (see Table 3).

2005). Product innovations are subject to the survey every three years. Process innovations are not subject to the survey at all.[11]

The qualification variable is based on occupational status, which is reported in the employee's statistics of the LIAB. According to the typology of Blossfeld (1985), an employee is classified as high qualified if he or she performs a job as an engineer, scientist, or manager. These occupations usually require formal education of the tertiary level. Alternatively, the formal education (tertiary degree) is used as qualification variable.[12]

The second variable stemming from the LIAB is experience. To control for different stocks of work experience, three categories of job tenure within the firm are distinguished (up to 1 year, 1-5 years, above 5 years). The other variables are taken from panel survey, so the information rely on the firm's own assessment. Firm size is measured by the logarithm of the number of employees. Export intensity is defined as the share of sales abroad. Further training activities are measured by the ratio of further training participants to the number of employees. The remaining control variables are implemented as dummy variables. The R&D variable is set to 1 if the firm is engaged in R&D activities or cooperation. If the firm rates its profitability as at least 'good' the corresponding dummy is set to 1. Due to lacking differentiation, the age of the firm has to be implemented as binary variable, too. A value of 1 is assigned if the enterprise was founded before 1990. Foreign ownership is set to 1 if the majority of the firm is owned by foreigners. The value 1 is assigned to the equipment dummy if the firm rates its technological level as 'state of the art'. Of course, the East dummy is 1 if the firm is located in the area of the former GDR.

The probit estimation is performed for the most recent year available, which is 2004. After the exclusion of non-manufacturing firms, firms with less than 10 employees and firms with missing values, 1,307 firms remain in the sample. The data about the innovation activity refer to the period of two years preceding the survey, which has been carried out in June 2004. The exogenous variables relate to 2002, i.e. the year before the innovation.[13]

The implementation of lagged variables is necessary to address the problem of endogeneity. Because innovation may itself lead to adjustments of the production system, the exogenous variables should measure the inputs before innovation took place. The use of a lagged model meets – at least to some degree – the problem of causality.

---

11 Information on organizational innovations, related to management, labor organization, quality control etc., is available. But since organizational innovations follow a very different logic, especially in the sectoral perspective (*Lam* 2005), we exclude them from our analysis.

12 As to be seen in Chapter 4, the qualification variable based on occupational status is a more suitable concept since the operationalisation via formal education includes employees with a tertiary degree though, performing jobs being not classified as highly qualified.

13 Due to data availability, only the further training variable refers to 2001. Values of the R&D variables are taken from 2004, because earlier surveys do not contain information about R&D cooperation.

4 Empirical Results

4.1 Descriptive Analysis

Regarding innovation activities in the four sectoral groups, we can confirm the innovation patterns described by Pavitt (1984). Science based industries and specialized suppliers make up for 84 percent and 77 percent of product innovators respectively while supplier dominated and scale intensive industries only account for 67 and 55 percent respectively (see Table 1). The same pattern is found for the different types of innovation. Especially market novelties are primarily developed within the group of science based industries. Among companies of the supplier dominated sector, only 5 percent develop market novelties, whereas 30 percent of companies in the science based sectors are active in this field.[14]

Table 1:
Sector specific share of innovators (%) by types of innovation

Sector / *Share of innovators*	Supplier dominated industries	Scale intensive industries	Specialized suppliers	Science based industries
Product innovation	54.7%	67.2%	77.3%	83.8%
Improvement	52.2%	64.6%	73.1%	79.1%
New product	16.4%	25.1%	32.0%	32.4%
Market novelty	4.7%	11.8%	19.1%	29.1%
Organizational innovation	63.4%	66.8%	70.6%	70.9%
Sample size	232	618	309	148

Source: LIAB 2001-2004.

A similar picture arises from the qualification structure (see Table 2, first row). The share of employees with a tertiary education ranges between 5 and 15 percent. Supplier dominated and scale intensive industries employ relatively few formally high-qualified employees, whereas specialized suppliers and science based industries employ more people with a higher education degree (12 and 15 percent respectively).

According to the occupational status (see Table 2, second row), the share of higher qualified employees (engineers, scientists, and managers) ranges between 4 and 11 per-

14 Furthermore, Table 1 shows, that organizational innovations differ much less across the four groups. As mentioned before, they are subject to a different pattern of innovation behaviour. Thus, the decision to restrict the analysis to product innovations is supported by the data.

cent.[15] The highest share of high-qualified employees arises in such industries that are above average active in product innovation. Thus, our first hypothesis can be confirmed through the descriptive data analysis.

Table 2:
Sector specific share of high qualified employees

Sector / *Qualification indicator*	Supplier dominated industries	Scale intensive industries	Specialized suppliers	Science based industries
High qualification - measured by formal education	5.1%	7.0%	11.9%	15.1%
High qualification - measured by occupational status	4.3%	5.7%	9.6%	11.1%

Source: LIAB 2001-2004.

We now look at the qualification structure of innovative and non-innovative firms within the Pavitt categories (see Table 3). For the low innovation sectors (supplier dominated and scale intensive industries) the employment of high-qualified people is not or only slightly higher in companies that are active in product innovation. Remarkable differences arise among innovators and non-innovators in specialized suppliers and science based industries. In both sectoral groups the level of qualification is obviously higher for innovators than for non-innovators.[16] Thus, there is some descriptive evidence that qualification is more important in companies concerned with original innovations than in low innovation sectors that mostly take over and adapt external technology or hardly fulfil own development activities. Therefore, Hypothesis 2 seems to be supported by the descriptive analysis too.

One can assume that the higher share of qualified employees, especially among innovators in the group of specialized suppliers and science based industries, is an expression of the fact that these firms employ more R&D personnel than others. Thus, in a further step we look at the differences in the share of high qualified employees according to the R&D participation of firms (see Table 4). Apart from supplier dominated industries, the share of high qualified employees is higher in firms with own R&D activities compared to firms without R&D activities. This effect in especially visible in the group of specialized suppliers (12.4% versus 5.7%).

15 As indicated above (Footnote 11), there are employees with a tertiary degree, but not working in positions that are classified as high qualified. This is shown by the fact that the share of high-qualified employees – measured by formal education is higher than the share of high qualified employees – measured by occupational status (see Table 2).

16 Within the science based industries one exception occurs: The share of high-qualified employees in companies, which upgrade their product range (‘new product’) is lower than in non innovative companies.

Table 3:
Sector specific share of high qualified employees (occupational status) according to innovators and non-innovators and type of innovation

Sample *Type of Innovation*	Supplier dominated industries		Scale intensive industries		Specialized suppliers		Science based industries	
Innovation (yes/no)	*yes*	*No*	*Yes*	*no*	*yes*	*no*	*yes*	*no*
Product innovation	4.0%	4.7%	5.7%	5.6%	10.4%	6.7%	11.5%	9.2%
Improvement	4.0%	4.6%	5.7%	5.5%	10.8%	6.4%	11.3%	10.3%
New product	4.4%	4.3%	5.9%	5.6%	10.8%	9.0%	10.2%	11.6%
Market novelty	6.8%	4.2%	6.3%	5.6%	14.0%	8.6%	12.5%	10.5%

Source: LIAB 2001-2004.

Table 4:
Sector specific share of high qualified employees (occupational status) according to R&D activity

Sample *R&D participation*	Supplier dominated industries	Scale intensive industries	Specialized suppliers	Science based industries
R&D existent	4.2%	6.5%	12.4%	12.3%
R&D nonexistent	4.3%	5.0%	5.7%	9.1%

Source: LIAB 2001-2004.

Obviously, a high share of high qualified employees and R&D activities are interconnected. Therefore, we run the regression analyses also with an interaction term of human capital and R&D, expecting a positive impact on innovation.

4.2 Estimation Results

Firstly, we run the regression analysis with the full sample (see Table 5). When including qualification and R&D without interaction term (Model I), the qualification variable does not turn out to be significant.[17] Other commonly estimated effects stemming from R&D activity, firm size, and export intensity appear to be significant with the anticipated

17 For all estimations we present the coefficients for the linear relationship of the underlying latent variable. The coefficients indicate the sign and significance of influence, but are not interpretable in terms of magnitude.

positive direction of influence. Furthermore, the two dummies for the science based and the specialized supplier industries have a significant positive impact on the probability of a firm's product innovation activity which corresponds to our expectations.[18]

Table 5:
Regression results of the probit estimation without interaction between R&D and qualification (Modell I) and with interaction (Modell II) (full sample)

Dependent Variable: Product innovation	*Model I (no interaction of qualification and R&D)*		*Model II (interaction of qualification and R&D)*	
	Coefficient	*z-value*	*Coefficient*	*z-value*
High qualification (occupational status)	-0,938	-1.61	-2.2565***	-2.82
R&D activities	1.201***	11.85	0.9711***	7.14
Interaction R&D – high qualification	-	-	3.2868**	2.41
Further training	0.150	0.66	0.1304	0.57
Job tenure max. 1 year	0.621	1.38	0.5893	1.31
Job tenure 1-5 years	0.292	1.51	0.2505	1.29
Firm size	0.187***	4.76	0.1963***	4.95
Export intensity	0.941***	4.62	0.9516***	4.63
Profitability	0.138	1.55	0.1497*	1.65
Equipment	0.019	0.19	0.0068	0.07
Age of the firm	0.021	0.19	0.0243	0.22
East	0.046	0.45	0.0562	0.55
Foreignness	0.015	0.11	-0.0005	-0.00
Scale intensive industry	0.063	0.56	0.0646	0.58
Specialized supplier	0.230*	1.70	0.2118	1.56
Science based industry	0.311*	1.75	0.3195*	1.78
Constant	-1.293***	-5.10	-1.2436***	-4.88
Sample size	1,307		1,307	
LR-Test	410.96***		417.78***	
McFadden R2	0.255		0.259	

Significance levels: *** 1%, ** 5%, * 10%.

Source: LIAB 2001-2004.

18 The results with respect to the qualification variable do not change when we exclude the R&D variable.

When we include an interaction term of qualification and R&D (Model II), the qualification variable turns out to be significant, but with a negative sign while the interaction term exhibits a significantly positive impact. This means that if R&D and qualification occur together in a firm, they clearly have a positive impact on the firm's propensity to carry out a product innovation. The negative sign of the qualification variable implies that high qualified personnel in a firm without R&D rather hinders innovation. However, this somehow surprising effect might stem from firms in the sample, which have a high share of qualified people (engineers, scientists and managers), but do not engage in any product innovation activity.

As we have seen in the descriptive part, the correlation between qualification and sectoral innovation patterns is quite high. Thus, the impact of the human capital variable could possibly be covered by the dummy variables for the Pavitt categories. In order to control for this, we run the regressions separately for sectoral sub-samples according to Pavitt's industry categories (see Table 6). But here again, the qualification variable does not appear to have a significantly positive (basic) effect. The interaction term exhibits a significantly positive impact only in the group of specialized suppliers while the basic effect of qualification is significantly negative here. This finding might be related to the fact that in specialized supplier firms the R&D and production activities are closely connected (e.g. production of special equipment in small charges or single-unit according to particular customer order).

A similar picture arises if the dependent innovation variable is disaggregated into the three types of product innovations: improvement, new product, or market novelty (see Appendix, Tables 1-2).

One explanation for the sector specific findings might be the occurrence of differences in the qualification level especially between and not within the sectoral innovation categories. Within the Pavitt categories, firms differ only slightly in respect of the share of high skilled employees, and thus, innovation activity is not affected. This might indicate that in terms of the employment of high-skilled persons, the qualitative characteristics could be more important than quantitative ones. Although the quantity of high-skilled employees differs only slightly within the sectoral groups, highly qualified staff could differ in terms of their specific discipline, university background, and respective imparted knowledge and skills. Descriptive statistics, however, reveal that this is only partly true. At least for the specialized suppliers, there are clear variations in the share of highly qualified employees.

Table 6:
Regression results of the Probit estimation of Model II (with interaction)

	Supplier dominated industries	*Scale intensive industries*	*Specialized suppliers*	*Science based industries*
Dependent Variable: Product innovation	*Coefficient (z-value)*	*Coefficient (z-value)*	*Coefficient (z-value)*	*Coefficient (z-value)*
High qualification (occupational status)	-1.7072 (-0.92)	-1.9408 (-1.45)	-2.6019* (-1.66)	-1.6265 (-0.70)
R&D activities	1.5566*** (3.57)	0.8332*** (4.24)	0.8402*** (2.71)	1.1902** (2.04)
Interaction R&D – high qualification	1.5856 (0.22)	3.5061 (1.40)	4.1660* (1.80)	6.5115 (1.18)
Further training	2.0535** (2.41)	-0.0103 (-0.03)	0.0589 (0.12)	-0.5668 (-0.77)
Job tenure max. 1 year	-0.1666 (-0.17)	0.8692 (1.37)	1.2513 (1.17)	-4.5096* (-1.71)
Job tenure 1-5 years	0.8625* (1.76)	0.4721* (1.64)	-0.2133 (-0.51)	-0.8964 (-1.42)
Firm size	0.1705* (1.67)	0.2032*** (3.69)	0.2928*** (2.98)	0.1913 (1.37)
Export intensity	1.9098*** (3.19)	1.2821*** (3.96)	0.7381* (1.78)	-0.5538 (-0.89)
Profitability	0.1181 (0.55)	0.1527 (1.21)	0.1748 (0.87)	0.3375 (0.98)
Equipment	-0.0898 (-0.38)	-0.0831 (-0.62)	0.0146 (0.07)	0.3287 (0.85)
Age of the firm	-0.0780 (-0.28)	0.1726 (1.13)	-0.2492 (-1.03)	0.2349 (0.58)
East	-0.1017 (-0.42)	0.1454 (1.02)	0.0245 (0.10)	0.4897 (1.21)
Foreignness	-0.1920 (-0.51)	0.1510 (0.73)	-0.3559 (-1.09)	0.6049 (1.27)
Scale intensive industry	-	-	-	-
Specialized supplier	-	-	-	-
Science based industry	-	-	-	-
Constant	-1.4308** (-2.06)	-1.4101*** (-4.10)	-1.0296* (-1.87)	-0.4630 (-0.49)
Sample size	232	618	309	148
LR-Test	90.12**	176.85***	95.29*	47.74
McFadden R2	0.282	0.226	0.288	0.364

Significance levels: *** 1%, ** 5%, * 10%, z-Values in Parentheses.

Source: LIAB 2001-2004.

5 Conclusions

The descriptive analysis reveals significant differences with respect to the share of highly qualified employees between sectors distinguished according to the classical innovation patterns described by Pavitt. Sectors with a high share of highly qualified employees are characterized by product innovation activities clearly above average (specialized suppliers and science based industries). Furthermore, within the sectoral clusters qualification seems to be particularly important for companies that are engaged in original innovations. Thus, descriptive findings support our hypotheses.

However, the regression results for the tested specifications do not reveal significantly positive coefficients for the qualification variables. Instead, we observe a significantly negative effect of qualification when we introduce an interaction term of R&D and qualification. This indicates that a high share of qualification as such is not enough as a driving force for product innovation. The findings suggest that qualification drives innovation only when the qualified people focus on innovative activities (R&D) – indicated by the significantly positive sign of the interaction term.

However, these are preliminary conclusions. The results call for further specification and correlation tests to be carried out. One further step could be an alternative operationalisation of the qualification variable (inclusion of technical assistants, exclusion of managers etc.).

To sum up, we find significant differences in the qualification levels between innovative and non-innovative firms, but until now we cannot statistically verify a positive impact of the share of highly qualified staff on the probability of product innovation. In the case that further specification test do not reveal other results, further research should examine the question whether there are rather qualitative than quantitative aspects determining a firms' innovative power.

References

Aghion, P.; Howitt, P. W. (1998): Endogenous Growth Theory. The MIT Press: Cambridge.

Alda, H. (2005): Betriebe und Beschäftigte in den Linked-Employer-Employee-Daten – LIAB des Instituts für Arbeitsmarkt- und Berufsforschung. FDZ-Datenreport 01/2005. Nürnberg.

Alda, H.; Herrlinger, D. (2005): LIAB-Datenhandbuch. Version 1.0. FDZ Datenreport 07/2005. Nürnberg.

Barro, R. J.; Sala-i-Martin, X. (1998): Wirtschaftswachstum. Wolls Lehr- und Handbücher der Wirtschafts- und Sozialwissenschaften. Oldenbourg Wissenschaftsverlag: München.

Blechinger, D.; Pfeiffer, F. (1999): Qualifikation. Beschäftigung und technischer Fortschritt. *Jahrbücher für Nationalökonomie und Statistik* 218(1+2), 128-146.

Blossfeld, H.-P. (1985): Bildungsexpansion und Berufschancen. Campus: Frankfurt.

BMBF (2006a): Die Hightech-Strategie für Deutschland. Bundesministerium für Bildung und Forschung: Berlin.

BMBF (2006b): Bericht zur technologischen Leistungsfähigkeit Deutschlands 2006. Bundesministerium für Bildung und Forschung: Berlin.

Bush, V. (1945): Science: The Endless Frontier. US Government Printing Office: Washington.

Dakhli, M.; De Clercq, D. (2003): Human Capital, Social Capital, and Innovation: A Multi Country Study. Vlerick Leuven Gent Working Paper 2003/18.

European Commission (2005): Communication from the Commission to the Council and the European Parliament. Common Actions for Growth and Employment: The Community Lisbon Programme. SEC(2005)981.

Fagerberg, J.; Mowery, D.; Nelson, R. (eds.) (2005): The Oxford Handbook of Innovation. Oxford University Press: Oxford.

Fagerberg, J.; Verspagen, B. (2006): Innovation studies – an emerging discipline (or what)? A study of the global network on innovation scholars. Paper presented at the SPRU 40th Anniversary Conference. University of Sussex. SPRU. September 11-13, 2006.

Gottschalk, S.; Janz, N. (2003): Bestimmungsfaktoren der Innovationstätigkeit, in: Janz, N.; Licht, G. (eds.): Innovationsforschung heute: Die Mannheimer Innovationspanels. Nomos-Verlagsgesellschaft: Baden-Baden, 17-39.

Grossman, G. M.; Helpman, E. (1997): Innovation and Growth in the Global Economy. MIT Press: Cambridge.

Günther, J.; Gebhardt, O. (2006): Auswärtige Betriebe und Innovationstätigkeit, in: IWH; IAB (eds.): Beschäftigungsanalysen mit den Daten des IAB-Betriebspanels – Tagungsband zum Workshop des IAB und IWH. IWH: Halle, 107-129.

Hatzichronoglou, T. (1997): Revision of the High-Technology Sector and Product Classification. STI Working Papers 1997/2. OECD: Paris.

Heidenreich, M. (2003): Die Debatte um die Wissensgesellschaft, in: Böschen, S.; Schulz-Schaeffer, I. (eds.): Wissenschaft in der Wissensgesellschaft. Westdeutscher Verlag: Wiesbaden, 25-51.

Hempel, T. (2003): Innovation im Dienstleistungssektor, in: Janz, N.; Licht, G. (eds.): Innovationsforschung heute. Die Mannheimer Innovationspanels. Nomos-Verlagsgesellschaft: Baden-Baden, 149-183.

Kline, S. J.; Rosenberg, N. (1986): An Overview of Innovation, in: Landau, R.; Rosenberg, N. (eds.): The Positive Sum Strategy. Harnessing Technology for Economic Growth. National Academy Press: Washington, 275-305.

Lam, A. (2005): Organizational Innovation, in: Fagerberg et al. (2005), 115-147.

Lucking, B. (2004): International Comparison of the Third Community Innovation Survey (CIS). TESE: London.

Lundvall, B.-Å. (2007): Higher Education. Innovation and Economic Development. Department of Business Studies. Aalborg University. Denmark. Paper presented at the World Bank's Regional Bank Conference on Development Economics. Beijing. January 16-17, 2007.

Lundvall, B.-Å.; Johnson, B. (1994): The Learning Economy. *Journal of Industry Studies* 1(2), 23-42.

Malerba, F. (2005): Sectoral Systems: How and Why Innovation Differs across Sectors, in: Fagerberg et al. (2005), 380-406.

Nelson, R.; Phelps, E. (1966): Investment in humans, technological diffusion, and economic growth. *American Economic Review. Papers and Proceedings* 51(2), 69-75.

OECD (2005): Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data. OECD: Paris.

Pavitt, K. (1984): Sectoral patterns of technical change: Towards a taxonomy and a theory. *Research Policy* 6, 343-373.

Peneder, M. (2003): Industry Classification: Aim, Scope, and Techniques. *Journal of Industry, Competition, and Trade* 3(1-2), 109-129.

Peters, B. (2003): Innovation und Beschäftigung, in: Janz, N.; Licht, G. (eds.): Innovationsforschung heute. Die Mannheimer Innovationspanels. Nomos-Verlagsgesellschaft: Baden-Baden, 113-148.

Pianta, M. (2005): Innovation and Employment, in: Fagerberg et al. (2005), 568-598.

Rammer, C.; Peters, B.; Schmidt, T.; Aschhoff, B.; Doherr, T.; Niggemann, H. (2005): Innovationen in Deutschland. Ergebnisse der Innovationserhebung in der deutschen Wirtschaft. Nomos-Verlagsgesellschaft: Baden-Baden.

Reinberg, A.; Hummel, M. (2004): Fachkräftemangel bedroht Wettbewerbsfähigkeit der deutschen Wirtschaft. *Aus Politik und Zeitgeschichte* 28, 3-16.

Robinson, C.; Stokes, L.; Stuivenwold, E.; Van Ark, B. (2003): Industry Structure and Taxonomies, in: European Commission: EU Productivity and Competitiveness: An Industry Perspective. Can Europe Resume the Catching-up Process? Luxembourg: Office for Official Publications of the European Communities, 37-71.

Romer, P. M. (1986): Increasing Returns and Long-run Growth. *Journal of Political Economy* 94(5), 1002-1037.

Schultz, T. W. (1975): The Value of the Ability to Deal with Disequilibria. *Journal of Economic Literature* 13(3), 827-846.

Statistisches Bundesamt (2005): Hochschulstandort Deutschland 2005. Statistisches Bundesamt: Wiesbaden.

Statistisches Bundesamt (2006): Bevölkerung Deutschlands bis 2050. 11. Koordinierte Bevölkerungsvorausberechnung. Statistisches Bundesamt: Wiesbaden.

Tether, B.; Mina, A.; Consoli, D.; Gagliardi, D. (2005): A Literature Review on Skills and Innovation. ESRC Centre for Research on Innovation and Competition. University of Manchester: Manchester.

Appendix

Table 1:
Probit regression coefficients for qualification variable (Model I)

Dependent variable	Improvement		New product		Market novelty	
Sample	*Coefficient*	*z-value*	*Coefficient*	*z-value*	*Coefficient*	*z-value*
Entire Sample	-0.7747	-1.33	-0.1836	-0.36	1.0788*	1.94
Supplier dominated	-0.8389	-0.46	-0.2792	-0.13	4.0116	1.45
Scale intensive	-0.8564	-0.78	-0.0722	-0.07	0.8908	0.72
Specialized suppliers	-0.0795	-0.07	0.5712	0.67	1.2654	1.33
Science based	-1.2852	-0.88	-0.3261	-0.26	1.1706	1.12

Significance levels: *** 1%, ** 5%, * 10%.

Source: LIAB 2001-2004.

Table 2:
Probit regression coefficients for qualification variable (Model II)

Dependent variable	Improvement		New product		Market novelty	
Sample	*High Qualification*	*Interaction R&D/Qual.*	*High Qualification*	*Interaction R&D/Qual.*	*High Qualification*	*Interaction R&D/Qual.*
Entire Sample	-1.9197** (-2.36)	2.5374** (2.03)	-0.4526 (-0.52)	0.3918 (0.38)	-0.0881 (-0.08)	1.4975 (1.16)
Supplier dominated	-1.1430 (-0.61)	4.1388 (0.59)	-1.9867 (-0.81)	8.9289* (1.68)	4.5066 (1.55)	-3.8882 (-0.51)
Scale intensive industry	-1.8769 (-1.38)	3.3249 (1.34)	-0.8122 (-0.53)	1.3358 (0.66)	0.4073 (0.20)	0.7617 (0.31)
Specialized suppliers	-1.6026 (-1.02)	2.9326 (1.33)	-0.6944 (-0.40)	1.6565 (0.85)	-4.3317 (-1.22)	6.4348* (1.74)
Science based industry	-2.8216 (-1.04)	2.2744 (0.67)	0.4588 (0.19)	-1.0829 (-0.38)	-2.2426 (-0.66)	3.8202 (1.07)

Significance levels: *** 1%, ** 5%, * 10%, z-Values in Parentheses.

Source: LIAB 2001-2004.

Table 3:
Description of regression variables

Variable	Scale	Year of reference	Description
		Endogenous variables	
Product innovation	0/1	2002-2004	At least one product innovation (product improvement, new product or market novelty)
Improvement	0/1	2002-2004	At least one product improvement
New Product	0/1	2002-2004	At least one new product or extension of product range
Market novelty	0/1	2002-2004	At least one market novelty
		Exogenous variables	
High qualification (occupational status)	%	2002	Share of engineers, scientists, and managers within the firm
Job tenure max. 1 year	%	2002	Share of employees with max. 1 year job tenure within the firm
Job tenure 1-5 years	%	2002	Share of employees with 1-5 years job tenure within the firm
R&D activities	0/1	2004	Engagement in R&D activities or cooperation
Firm size	log	2002	Log. number of Employees
Export intensity	%	2002	Share of sales abroad
Profitability	0/1	2002	At least good profitability (Assessment better than 3 on a range of 1-5)
Equipment	0/1	2002	At least good technological standard (Assessment better than 3 on a range of 1-5)
Further training	%	2001	Share of further training participants on total employees
Age of the firm	0/1	2002	Firm foundation before 1990
East	0/1	2002	Firm located in East-Germany
Foreignness	0/1	2002	Majority of firm owned by foreigners
Scale intensive industry	0/1	2002	According to Pavitt (1984) and Robinson et al. (2003), see Appendix table 7.
Specialized suppliers	0/1	2002	
Science based industry	0/1	2002	

Table 4:
Pavitt Taxonomy (producing sector without construction)

Category	International Standard Industrial Classification of All Economic Activities. Revision 3 (1990) ISIC (Rev. 3)
Supplier dominated industries	Agriculture (01); Forestry (02); Fishing (05); Textiles (17); Clothing (18); Leather and footwear (19); Wood & products of wood and cork (20); Pulp, paper & paper products (21); Printing & publishing (22); Furniture, miscellaneous manufacturing, recycling (36-37).
Scale intensive industries	Mining and quarrying (10-14); Food, drink & tobacco (15-16); Mineral oil refining, coke & nuclear fuel (23); Rubber & plastics (25); Non-metallic mineral products (26); Basic metals (27); Fabricated metal products (28); Motor vehicles (34); Building and repairing of ships and boats (351); Aircraft and spacecraft (353); Railroad equipment and transport equipment n.e.c. (352+359); Electricity, gas and water supply (40-41).
Specialized suppliers	Mechanical engineering (29); Office machinery (30); Insulated wire (313); Electronic valves and tubes (321); Telecommunication equipment (322); Scientific instruments (331); Other instruments (33-331).
Science based industries	Chemicals (24); Other electrical machinery & apparatus (31-313); Radio and television receivers (323).

Source: Robinson et al. (2003).