

**Does qualification drive innovation?
A microeconometric analysis using linked-employer-
employee data**

**-Preliminary version-
February 2007**

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*Submission for the Annual Congress of the Verein für Socialpolitik "Education
and Innovation"*

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Abstract

Degree-level science and engineering skills as well as management and leadership skills are often referred to 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. Our work in progress uses unique micro data (LLAB) 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, however, not substantially increase the probability to be an innovative firm.

1 Introduction

Education, R&D and innovation rank very high in today's policy agendas. Frequently cited 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 2006) 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/Hummel 2004). 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, 18).

In the following 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, 575ff; Blechinger/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 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/De Clercq (2003) finds clear evidence for the importance of human capital as a determinant of innovation. The results are based on a cross-country analysis, where innovation is only 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, 214ff) 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. A study by Günther/Gebhardt (2005)

involves 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 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.

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/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/Helpman 1997). There are various specifications in new growth models that particularly stress the role of human capital (Barro/Sala-i-Martin 1998, 200ff), but the wide spectrum would go beyond of 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 a black box phenomenon in economic

theory. In search for a stronger theoretical backing at the firm level, we additionally consult theoretical approaches belonging to the interdisciplinary field of innovation studies.¹

Innovation studies

Contributions, usually assigned to the area of innovation studies or systemic innovation theory support a holistic view and add to a better understanding of the nature of the innovation process as such.²

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

As regards human capital more specifically, Nelson/Phelps (1966) documented in a simple growth model that better educated people fulfil regular activities more effectively, and 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/Johnson 1994). He states that there are two ways by which higher education impacts innovation: On the one hand, higher education graduates can operate as basic innovators, i.e. they invent and develop 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.

¹ For an insightful discussion of “innovation studies” as a discipline see Fagerberg/Verspagen (2006).

² For an overview see Fagerberg/Mowery/Nelson (2005).

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 as regards 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 with regard to their technological or innovation regime.³

The simplest classification, frequently used in international comparative studies, is the one from the OECD, developed by Hatzichronoglou (1997). According to R&D intensity 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 aspects like supplier-customer relations, learning-by-doing or learning-by-interacting, etc., too. 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.⁴

(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 close relationship with frequent users. Firms in this category are strongly focused on product innovations and require skills of interactive learning, 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, specialist product design, development skills as well

³ For a recent overview of industry classifications in general, see e.g. Peneder (2003).

⁴ 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 the appendix (see Table 7).

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 thought 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.

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 with the empirical literature focusing on determinants of innovation activity the following exogenous variables are taken into account:⁵

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.⁶

5 A discussion of the variables selected here can be found, for example, in Günther/Gebhardt (2006) and Gottschalk/Janz (2003).

6 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 anymore (Gottschalk/Janz 2003).

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. So, 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.

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 the firm itself 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. On the other hand, 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:

$$y_i^* = \alpha + \beta HK_i + \gamma' X_i + e_i$$

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

Where y_i denotes our binary outcome, which becomes 1 if firm i is active in product innovation, and y_i^* 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. γ denotes a vector of coefficients for the above described exogenous control variables in X_i , α represents the constant, and ϵ denotes the error term. The estimations are limited to the manufacturing sector (without construction) and to firms with at least 10 employees.⁷ The model is estimated for the entire sample and separately for each of the four sub-samples according to the Pavitt taxonomy.

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.⁸ 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

⁷ 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.

⁸ For a description of the data set see Alda (2005) and Alda/Herrlinger (2005)

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.⁹ 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 2005). Product innovations are subject to the survey every three years. Process innovations are not subject to the survey at all.¹⁰

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 is used as qualification variable.¹¹

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

⁹ A description of endogenous and exogenous variables is given in the appendix (see Table 6).

¹⁰ 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.

¹¹ As can be seen in chapter 4, the qualification variable based on occupational status is the more suitable concept since the operationalization via formal education includes employees with a tertiary degree but performing jobs not classified as highly qualified.

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.¹²

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.

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.¹³

¹² 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.

¹³ 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.

Table 1: Sector specific share of innovators by innovation category

<i>Share of innovators (in %)</i>	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 for 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 percent.¹⁴ The highest share of high-qualified employees arises in such industries that are above average active in product innovation. Thus, hypothesis 1 can be confirmed through the descriptive data analysis.

Table 2: Sector specific share of high qualified employees

<i>Qualification indicator</i>	<i>Sample</i>	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.

¹⁴ 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).

In both sectoral groups the level of qualification is obviously higher for innovators than for non-innovators.¹⁵ 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.

Table 3: Sector specific share of high-qualified employees^a of innovators and non-innovators by innovation category

<i>Sample</i> <i>Innovation type</i>	Supplier dominated industries		Scale intensive industries		Specialized suppliers		Science based industries	
	<i>yes</i>	<i>No</i>	<i>Yes</i>	<i>no</i>	<i>yes</i>	<i>no</i>	<i>yes</i>	<i>no</i>
<i>Innovation (yes/no)</i>								
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%

^a Measured by occupational status.

Source: LIAB 2001-2004.

4.2 Estimation results

In the regression analysis carried out with the full sample, the qualification variable does not turn out to be significant.¹⁶ Other commonly estimated effects stemming from firm size, R&D activity, and export intensity appear significantly with the anticipated 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. As we have seen in the descriptive part, the correlation between qualification level and sectoral innovation patterns is quite high. Thus the impact of the human capital variable could be covered by dummy variables for the Pavitt categories.

¹⁵ 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.

¹⁶ 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.

Table 4: Regression results of the Probit estimation (full sample)

<i>Dependent Variable:</i> <i>Product innovation</i>	<i>Coefficient</i>	<i>z-value</i>
High qualification (occupational status)	-0,848	-1,47
R&D activities	1,015**	9,46
Further training	0,092	0,42
Job tenure max. 1 year	0,531	1,21
Job tenure 1-5 years	0,343	1,80
Firm size	0,205**	5,30
Export intensity	1,083**	5,44
Profitability	0,102	1,17
Equipment	0,034	0,37
Age of the firm	0,035	0,33
East	0,018	0,19
Foreignness	-0,005	-0,03
Scale intensive industry	0,100	0,92
Specialized supplier	0,284*	2,14
Science based industry	0,370*	2,14
Constant	-1,299**	-5,24
Sample size	1307	
LR-Test	354,37**	
McFadden R2	0,220	

Significance levels: ** 1%, * 5%

Source: LIAB 2001-2004.

To control for this, we run the regressions separately for sectoral subsamples according to the Pavitt classification (see Appendix, Tables 1-4). But here again, the qualification variable does not appear with a significant coefficient in the regression results. 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, Table 5). We have two possible explanations for these rather unexpected results.

First, the strongest differences in the qualification levels occur between the sectoral innovation categories. Within the Pavitt categories, firms differ only slightly with respect to 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, the highly qualified staff could differ in terms of his or her 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.

This leads to the second possible explanation, namely, that there are one or more other variables that capture the effect of the qualification. The R&D dummy could, for example, be highly correlated with the share of highly qualified employees in a company. In this respect the share of high-qualified employment is expected to be higher in companies that are engaged in R&D. Existing empirical analyses support this view. An empirical study for the UK, for example, found that the share of university graduates in total employment is clearly higher among firms that are engaged in R&D (Tether et al. 2005). Another empirical study into the determinants of innovation also shows that the human capital variable becomes significantly positive (or increases in significance) when excluding R&D from the regression (Rammer et al. 2005). To complete our analysis, we intend to verify these explanations through further specification tests. So far, we can only conclude that the variation in the share of highly qualified employees that is not covered by other variables has no impact on a firm's probability to be innovative.

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 these companies that are engaged in original innovations. Thus, descriptive findings support our hypotheses.

However, the regression results for the tested specifications do not reveal significant coefficients for the qualification variables. These results would indicate that the share of highly qualified employees does not substantially increase the probability of firms' innovation activity. However, this can only be a preliminary conclusion. The hitherto results call for other specification and correlation tests. It is probable that the share of highly qualified employees is strongly correlated with the fact that a firm is engaged in R&D. In this case the impact of a higher share of graduates among the workforce is covered by the R&D dummy in our model specification.

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 Nr. 01/2005. Nürnberg.
- Alda, H. & Herrlinger, D. (2005): *LIAB-Datenhandbuch. Version 1.0*. FDZ Datenreport Nr. 07/2005. Nürnberg.
- Barro, R. J. & Sala-i-Martin X. (1998): *Wirtschaftswachstum*, Wolls Lehr- und Handbücher der Wirtschafts- und Sozialwissenschaften, Oldenbourg Wissenschaftsverlag.
- Blossfeld, H.-P. (1985): *Bildungsexpansion und Berufschancen*. Frankfurt: Campus.
- Blechinger, D. & Pfeiffer, F. (1999): *Qualifikation, Beschäftigung und technischer Fortschritt*. In: *Jahrbücher für Nationalökonomie und Statistik* 218 (1+2), 128-146.
- BMBF (2006): *Die Hightech-Strategie für Deutschland*. Berlin: Bundesministerium für Bildung und Forschung (BMBF).
- Bush, V. (1945): *Science: The Endless Frontier*. Washington: US Government Printing Office.
- Dakhli, M. & De Clercq D. (2003) : *Human Capital, Social Capital, and Innovation : A Multi Country Study*. Vlerick Leuven Gent Working Paper No. 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. Oxford University Press.
- 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. (Hrsg.): *Innovationsforschung heute: Die Mannheimer Innovationspanels*. Baden-Baden: Nomos, 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 (Hrsg.): *Beschäftigungsanalysen mit den Daten des IAB-Betriebspanels – Tagungsband zum Workshop des IAB und IWH*, 107-129.
- Hatzichronoglou, T. (1997): *Revision of the High-Technology Sector and Product Classification*. STI Working Papers 1997/2. Paris: OECD.
- Heidenreich, M. (2003): Die Debatte um die Wissensgesellschaft. In: Bösch, S. & Schulz-Schaeffer, I. (eds.): *Wissenschaft in der Wissensgesellschaft*. Wiesbaden: Westdeutscher Verlag, 25-51.
- Hempel, T. (2003): Innovation im Dienstleistungssektor. In: Janz, N. & Licht, G. (Hrsg.): *Innovationsforschung heute. Die Mannheimer Innovationspanels*. Baden-Baden: Nomos, 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*. Washington: National Academy Press, 275-305.
- Lam, A. (2005): Organizational Innovation. In: Fagerberg, J. et al. (eds.) (2005), 115-147.
- Lucking, B. (2004): International Comparison of the Third Community Innovation Survey (CIS). London: TESE (Technology, Economics, Statistics, and Evaluation).
- 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. In: *Journal of Industry Studies* 1 (2), 23-42.
- Malerba, F. (2005): Sectoral Systems: How and Why Innovation Differs across Sectors. In: Fagerberg, J. et al. (eds.) (2005), 380-406.
- Nelson, R. & Phelps, E. (1966): Investment in humans, technological diffusion, and economic growth. In: *American Economic Review, Papers and Proceedings* 51 (2), 69-75.
- OECD (2005): *Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data*, Paris, OECD.

-
- Pavitt, K. (1984): Sectoral patterns of technical change: Towards a taxonomy and a theory. In: *Research Policy* 6, 343-373.
- Peneder, M. (2003): Industry Classification: Aim, Scope, and Techniques. In: *Journal of Industry, Competition, and Trade* 3 (1-2), 109-129.
- Peters, B. (2003): Innovation und Beschäftigung. In: Janz, N. & Licht, G. (Hrsg.): *Innovationsforschung heute. Die Mannheimer Innovationspanels*. Baden-Baden: Nomos, 113-148.
- Pianta, M. (2005): Innovation and Employment. In: Fagerberg, J. et al. (eds.) (2005), 568-598.
- Rammer, C. et al. (2005): Innovationen in Deutschland. Ergebnisse der Innovationserhebung in der deutschen Wirtschaft. Baden-Baden: Nomos.
- Reinberg, A. & Hummel, M. (2004): Fachkräftemangel bedroht Wettbewerbsfähigkeit der deutschen Wirtschaft. In: *Aus Politik und Zeitgeschichte* 28, 3-16.
- Robinson, C. & Stokes, L. & Stuijvenwold, 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. In: *Journal of Economic Literature*, 13 (3), 827-846.
- Statistisches Bundesamt (2006): *Bevölkerung Deutschlands bis 2050. 11. Koordinierte Bevölkerungsvorausberechnung*. Wiesbaden: Statistisches Bundesamt.
- Statistisches Bundesamt (2005): *Hochschulstandort Deutschland 2005*. Wiesbaden: Statistisches Bundesamt.
- 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.

Appendix

Table 1: Probit regression results (Supplier dominated industries)

<i>Dependent Variable: Product innovation</i>	<i>Coefficient</i>	<i>z-value</i>
High qualification (occupational status)	-1,669	-0,94
R&D activities	1,323**	4,10
Further training	1,769*	2,23
Job tenure max. 1 year	-0,432	-0,45
Job tenure 1-5 years	0,854	1,76
Firm size	0,215*	2,19
Export intensity	1,973**	3,55
Profitability	0,055	0,26
Equipment	-0,107	-0,47
Age of the firm	-0,092	-0,34
East	-0,114	-0,49
Foreignness	-0,200	-0,56
Constant	-1,406*	-2,12
Sample size	232	
LR-Test	74,95**	
McFadden R2	0,235	

Significance levels: ** 1%, * 5%

Source: LIAB 2001-2004.

Table 2: Probit regression results (Scale intensive industries)

<i>Dependent Variable:</i> <i>Product innovation</i>	<i>Coefficient</i>	<i>z-value</i>
High qualification (occupational status)	-0,843	-0,79
R&D activities	0,843**	5,70
Further training	-0,037	-0,12
Job tenure max. 1 year	1,018	1,64
Job tenure 1-5 years	0,562*	1,99
Firm size	0,216**	3,99
Export intensity	1,436**	4,50
Profitability	0,100	0,81
Equipment	-0,042	-0,32
Age of the firm	0,206	1,38
East	0,126	0,91
Foreignness	0,159	0,79
Constant	-1,486**	-4,41
Sample size	618	
LR-Test	149,83**	
McFadden R2	0,191	

Significance levels: ** 1%, * 5%

Source: LIAB 2001-2004.

Table 3: Probit regression results (Specialized suppliers)

<i>Dependent Variable:</i> <i>Product innovation</i>	<i>Coefficient</i>	<i>z-value</i>
High qualification (occupational status)	-0,385	-0,36
R&D activities	1,147**	4,87
Further training	-0,006	-0,01
Job tenure max. 1 year	0,727	0,70
Job tenure 1-5 years	0,038	0,09
Firm size	0,269**	2,80
Export intensity	0,777*	1,97
Profitability	0,133	0,68
Equipment	-0,034	-0,16
Age of the firm	-0,260	-1,10
East	-0,051	-0,22
Foreignness	-0,354	-1,12
Constant	-0,874	-1,64
Sample size	309	
LR-Test	85,47**	
McFadden R2	0,259	

Significance levels: ** 1%, * 5%

Source: LIAB 2001-2004.

Table 4: Probit regression results (Science based industries)

<i>Dependent Variable:</i> <i>Product innovation</i>	<i>Coefficient</i>	<i>z-value</i>
High qualification (occupational status)	-0,020	-0,01
R&D activities	1,390**	3,81
Further training	-0,352	-0,54
Job tenure max. 1 year	-3,174	-1,33
Job tenure 1-5 years	-0,923	-1,52
Firm size	0,136	1,04
Export intensity	-0,300	-0,53
Profitability	0,263	0,83
Equipment	0,474	1,33
Age of the firm	0,123	0,34
East	0,230	0,64
Foreignness	0,537	1,21
Constant	-0,158	-0,18
Sample size	148	
LR-Test	34,07**	
McFadden R2	0,260	

Significance levels: ** 1%, * 5%

Source: LIAB 2001-2004.

Table 5: Probit regression coefficients for qualification variable

Dependent variable	Improvement		New product		Market novelty	
	<i>Coefficient</i>	<i>z-value</i>	<i>Coefficient</i>	<i>z-value</i>	<i>Coefficient</i>	<i>z-value</i>
Entire Sample	-0,675	-1,18	-0,119	-0,23	1,095*	1,97
Supplier dominated	-0,983	-0,55	-0,420	-0,20	3,802	1,31
Scale intensive	-0,827	-0,77	-0,011	-0,01	0,731	0,59
Specialized suppliers	0,175	0,17	0,667	0,79	1,326	1,41
Science based	-0,931	-0,67	-0,424	-0,34	1,370	1,31

Significance levels: ** 1%, * 5%

Source: LIAB 2001-2004.

Table 6: Description of regression variables

Variable	Scale	Year of reference	Description
<i>Endogenous variables</i>			
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
<i>Exogenous variables</i>			
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 7: 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).