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Abstract

Innovation is a key driver of technological progress and growth in a knowledge-based economy. There are various motives for individual firms to innovate: improving quality secures market leadership, introducing new products leads the firm into new markets, adopting new technologies could be seen as a catch-up strategy within an industry or an improvement of the firm's own products when the technology adopted is based on ideas from other industries. Firms can perform innovation activities in one or more of these areas or in none of them. We therefore raise the question of what types of firms tend to be more innovative, i.e. which firms innovate in more of these areas. For this purpose we employ firm-level survey data and combine it with administrative data from Germany's social security system. An ordered logit model is estimated using a variety of characteristics which describe the workforce employed and other firm-related variables, the regional environment where the firm is located, as well as industry and region fixed effects.

Keywords: firm innovation, labor diversity, ordered logit

JEL: J 44, O 31, R 12

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1. Introduction

Knowledge-based economies focusing on production and services need to be innovative in the long run in order to secure long-term welfare. In a global world where countries compete to create and produce the latest market-leading products, the innovation capacity of a country's own domestic industry is of particular importance. There are various types of innovation, namely the introduction of products new to the market, the improvement of the quality of existing products or the adoption of new technologies. In order to remain competitive in the long run it seems beneficial to consider all of these areas. However, innovation is costly and there is uncertainty regarding its success. According to existing literature, workforce diversity with respect to age, cultural background, human capital and occupations may improve the innovative capacity of an establishment. Then fewer resources are required to achieve more innovation. In this paper we investigate in particular what kinds of establishments are relatively more innovative and undertake more than one type of innovation. For this purpose an ordered logit model is estimated using German survey and administrative data. We consider establishment characteristics, the diversity of the workforce employed and possible regional spillover effects within industries. In addition, industry- and region-specific effects are taken into account. We provide evidence that (i) workforce diversity matters, (ii) spillover effects are present, (iii) the probability of innovating does not depend on the location and (iv) the marginal effects are strongest for performing two types of innovation, which means that establishments tend to spread their innovation capacity across various innovation types.

The paper is structured as follows. Section 2 provides a theoretical outline of innovation processes and considers relevant variables from a theoretical perspective. Section 3 reviews related empirical work. In Section 4 the data basis and the variables included are introduced, while in Section 5 the estimation issues are discussed and the results presented and interpreted. Finally, Section 6 concludes.

2. Theoretical background

Theoretical and empirical literature on innovation has been well examined, as innovation is seen as an important driver of economic growth. Individuals' or firms' motives for becoming innovative can be related to various theories. From an individual perspective, the creation of a new product or service may enable a person to become self-employed and to secure their income in the future. It may also provide an opportunity to leave unemployment. More frequently, however, innovation is explained from a firm perspective. Starting with the theory of Schumpeter's 'creative destruction', innovation is both a result and a key driver of the profit-seeking behavior of individual firms. Firms compete in a market and the firm that offers the newest product, or the one of the best quality, will enjoy relatively higher profits. Being the market leader demands innovation and especially product improvement. Another motive for firms to be innovative is also based on profit-seeking: namely entry into new markets. Offering products that are new to the market provides firms with the opportunity a monopoly rent, which can be seen as an additional premium over marginal costs, at least in the short run and possibly also in the long run. These theoretical models typically relate to a horizontal product market with an expanding variety of products (Romer 1990).

Both of these reasons for firms seeking to innovate are likely to require more intensive research and development. A third strategy aimed at boosting profits and improving the firm's own product is the adoption of other technologies. This may involve imitating competitors' products or may introduce technologies from firms in 'unrelated' sectors. All the concepts are discussed in the theoretical literature (see e.g. Grossman and Helpman, 1995) and research or innovative activities are typically assumed to be relevant. Thus, innovation inputs can be linked to innovation outcomes, as suggested by Griliches (1979?). Griliches develops the concept of the knowledge production function. In this function, typically human-capital-related inputs of the research unit as well as factors external to the research unit are introduced. The external factors are intended to control for possible spillover effects because some parts of 'innovative capital' and knowledge are observable and therefore have characteristics of a public good. These external factors make innovation less costly. Being located in an innovative environment then reduces the overall cost of innovation, which ultimately makes innovation more likely. In accordance with the knowledge production function, many applied studies use conventional research and development inputs as explanatory variables, such as the stock or proportion of university graduates in the workforce in order to explain innovation outcomes, such as patent data or the likelihood of being innovative.

We have so far introduced motives for being innovative and factors that might be relevant for innovative activity. We now turn to the decision to become innovative: on the one hand innovation may lead to future profits; on the other hand innovation is costly and the probability of success might be small. Becoming innovative therefore depends on balancing the expected profits and the expected costs. Theoretical literature, such as Grossman and

Helpman (1995) or Baldwin (1999) frequently relates this trade-off to the concept of Tobin's Q (1969): If the expected discounted profit exceeds the costs of innovation, innovation is performed. Thus, for a given cost, the likelihood of being innovative should increase, the higher the expected profit is. From an empirical point of view the unobservable future profit is not available. However, in a general equilibrium setting the expected discounted profit may be expressed in terms of the current profit and parameters that influence the discounting (i.e. the depreciation rate, the (long run) interest rate on capital and possibly the growth rates of the capital or knowledge stock.

The theoretical outline provides important and relevant variables for explaining innovation in general. According to the knowledge production function, human capital variables, productivity and cost-related variables as well as variables describing the regional environment should be included in a regression. Profit-related measures control for the likelihood of becoming innovative and therefore also for the trade-off between costs and profits as stated by Tobin's Q.

3. Literature review

Many empirical studies support the theoretical literature and show that innovation raises growth and productivity. Cainelli et al. (2006) observed that especially investment in information and communication technologies (ICT) have an impact on growth and productivity. The study by Koellinger (2008) examines the relationship between innovation in internet-based technologies and firm performance. The results show that all types of innovation, such as Internet-enabled and non-Internet-enabled product or process innovations, have a positive effect on turnover and employment growth. Furthermore, firms that use Internet-enabled innovations have a higher likelihood of growth compared to firms that use non-Internet-based innovations. Crepon et al. (1998) provide evidence of a positive relationship between firm productivity and innovation output, even when keeping both the skill composition of labor and physical capital intensity constant. Thus, more productive firms tend to be more innovative.

In a cross-country comparison of France, Germany, Spain and the UK, Griffith et al. (2006) analyze the impact of innovation on productivity and obtain mixed results with respect to different types of innovation. For most countries, product innovation yields productivity gains.

Cassiman et al. (2010) state that a positive effect of exports on productivity found in the empirical studies is linked to the firms' innovation decisions. Their analyses for Spanish manufacturing firms provide strong evidence that product innovation raises firms' productivity significantly, but process innovation does not; and, as a consequence of product innovation, small firms without export activities become more likely to enter the export market. This line of argumentation is in line with the theoretical explanation of the Melitz (2003) model. For German companies operating in the service sector, however, Ebling and Janz (1999) provide evidence that export activities do not intensify innovation.

Simmie et al. (2002) analyze the relationship between the function of a city/region and innovation behavior. They find that in 'regional cities', such as Stuttgart or Milan, innovations are more closely linked to their regional and national economies than they are in 'global cities' such as Paris and London. This is related to knowledge spillovers in space and regional clusters. In regions where firms are more closely connected to the local economy, innovation boosts local productivity. On the other hand, innovations affect more than the local economy when firms are integrated in global markets and are located in 'global cities'. Other empirical work, such as that conducted by Duranton and Puga (2001) and Feldman and Audretsch (1999), take into account the role of diversity and city size on innovation. They find that larger, more diverse cities and regions are typically more innovative, which is in line with the evidence of Semmie et al. (2002). In addition, Feldman and Audretsch (1999) find that the degree of local competition fosters innovative activity more than a local monopoly does.
From a regional European perspective, Ozgen et al. (2011a) consider patent applications as innovative outcomes and find significant effects of the regional economic environment, supporting Griliches (1979) theory of knowledge-production. Pfirrmann (1994) focuses on regional innovation disparities in former West Germany while analyzing small and medium-sized firms: firm-specific factors have a greater effect on innovation efforts than factors associated with the regional environment. This evidence corresponds with that obtained by Sternberg (2009), who examines small and medium-sized European firms and finds that firm-level factors have a greater effect on the level of innovation activity than region-specific and external factors. The effect of the regional environment variables on firms' incentives to be more innovative, however, supports the theory, launched by Griliches (1979), that knowledge/human capital spillover is a driving force of long-run economic growth (e.g. Romer, 1990).

As suggested by the knowledge-production function theory, further studies demonstrate that firm innovation is positively influenced by research and development (R&D) activities (Thornhill 2006, Acs et al. 1994, Hall et al. 2009). The study conducted by Hall et al. (2009) for Italy shows that R&D intensity, firm size and investment in equipment raise the probability of performing process and product innovation. Although both types of innovation are positively related to firms' productivity, they find that process innovation has a greater effect.

The study by Almeida and Kogut (1997) uses patent data to examine the innovative ability of small firms in the semiconductor industry by focusing on their technological diversity and their integration within local knowledge networks. By comparing the innovation activity of start-ups and larger firms it is shown that small firms innovate in less 'crowded' areas when exploring new technological fields. They also observe that small firms have a stronger link to regional knowledge networks than large firms. Thus, the number of firms in a location may serve as an explanatory variable to capture network activities of cooperating firms. Related to this, the study by Baptista and Swann (1998) analyzes the effect of industrial regions on firms' innovation activities for the UK. By observing 248 manufacturing firms during the period from 1975 to 1982, they show that rising employment in a firm's own sector and region leads to an increase in the firm's own innovation activities.

The study conducted by Thornhill (2006) demonstrates that firm performance is affected by firm knowledge, industry dynamism and innovation. More specifically, while highly skilled labor is most profitable for a company's performance in dynamic environments, stable production industries profit more from investments in training. Zucker et al. (1998) show for the USA that the presence and availability of intellectual human capital, measured as "star" bio-technology scientists, is the reason for newly founded firms in the field of biotechnology in the particular region. This study concludes that localized intellectual human capital plays a key role in the development of the bio-tech industry. Therefore, industry-specific knowledge and its availability lead, first, to innovation which, in a second stage, leads to regional industrial development and firm formation. There are also sector-specific differences: by comparing cost functions and investment levels in the research and development of public and private firms, Nett (1994) finds that private firms are more innovative than public ones. Frenkel et al. (2001) compare Israeli and German industrial firms by analyzing firm characteristics, location and regional innovation. They conclude that firms in high-tech industries are significantly more innovative than those in traditional sectors.

The literature review reveals, first, that industry- and region-specific effects have to be considered, and second, that most of the factors discussed in the theoretical literature have been tested empirically and show the expected signs. A third finding is that there are interdependencies between innovation, productivity and export behavior, which leads to endogeneity concerns. Thus, it is possible to show correlation but not causal effects – a restriction which also exists in this study.

4. Description of data and variables

In the empirical analysis we use German survey data from the IAB Establishment Panel. We link this data basis with a special sample drawn from the IAB Employment History, which was aggregated to the establishment level. This data source is based on administrative data covering the entire population of all employees subject to social security. The self-employed and civil servants cannot therefore be observed. Despite this limitation, the data are highly reliable as they are used for calculating contributions to unemployment insurance. Because the IAB Employment History contains data on the entire population in employment subject to social security, we are able to compute additional regional measures for the region where each establishment is located. The administrative data is collected at establishment level and not firm level. A firm might operate at one or more establishments. We can only observe individual establishments and we cannot identify establishments belonging to the same firm. This limitation is due to data regulations and we have to accept it. However, it is the only existing data source for Germany that permits this kind of research.
Data on establishment characteristics are taken from the IAB Establishment Panel, which is not recorded on the basis of the social security system. Data on the workforce employed is taken from the IAB Employment History.
Our explanatory variable is derived from survey data for the years 1998, 2001, 2004, and from 2007 until 2010. Establishments were asked whether they had performed innovation activities in the previous year by introducing new products or improving existing products, or whether they had adopted new technologies. In this paper we do not focus on each binary outcome on its own and ask which variables are relevant for one of the innovation types but we investigate which establishments are more likely to perform various types of innovation.

From these binary outcomes we construct our dependent variable: the number of innovation activities at the establishment as a measure of the establishment's innovative capacity. It therefore takes values ranging from 0 to 3. In a first step we limit our investigation by not attempting to distinguish between the resulting combinations of innovation types.

Table 1 shows the distribution of the innovative capacity of individual establishments. It can be seen that on average more than 51% of all firms did not innovate at all. About 25% of all establishments innovate in one of the three areas, about 17% invest in two innovation types and, finally, less than 6% on average perform all three types of innovation. Thus, only a small proportion of establishments decide to build up a strong innovation capacity. The distribution of innovation activities is also very constant over time.

The last row reports the number of observations to be used in the model which we consider in the empirical part in more detail. It represents the minimum number of observations. The reported distribution of probabilities remains largely the same if the entire sample is considered.

Table 1: Distribution of innovation activities in establishments

as %	No innovation	Innovation in one area	Innovation in two areas	Innovation in three areas
1998	49.37	25.12	19.91	5.59
2001	53.40	23.56	17.93	5.11
2004	57.93	24.06	14.65	3.36
2007	47.87	23.26	20.66	8.21
2008	51.81	25.81	16.88	5.49
2009	49.38	26.09	18.43	6.10
2010	52.56	24.99	16.81	5.64
Average	51.91	24.66	17.77	5.65
No. obs.*	24,677	11,701	8,273	2,479

* The number of cases varies slightly between models as a result of missing data

Innovation capacity is explained by various variables. From the IAB Establishment Panel we use information about the legal form of the establishment. Two dummy indicators are set to 1 if the establishment is a sole trader or a private partnership company, respectively. The reference category therefore relates to establishments which are limited companies. Because innovation involves a certain degree of uncertainty and is therefore risky, sole traders and private partnerships are less likely to be innovative. In both of these cases establishment success is directly related to the owner's income, so risk aversion is higher.

Another dummy indicator is set to unity if the establishment has a foreign owner (Castellani and Zanfei, 2003). Foreign owners might have an interest in long-run company success with higher dividend payments. The establishments have to be relatively more innovative in order to secure this success.

The technical state of the machinery in the production process provides a proxy for productivity. As suggested in the existing work, a higher level of productivity is associated with a higher probability of becoming innovative. Because the information about the technical state of the machinery is categorized, we introduce a set of dummy variables that relate to each category; these are: new technology, moderate technology and old technology. The reference group is state-of-the-art technology.

We also control for the age of the establishments. There are several concerns regarding an age measure which relates, for example, to the number of years that the establishment has existed. First, the administrative data has been recorded since 1975. There is no information available on establishment foundation before 1975. Thus, 1975 is the earliest year of foundation for an establishment in the data. We have no information about when these establishments were really founded. Therefore, the establishment age is biased for all companies that already existed in 1975. Whereas this might be a relatively small bias, there is a similar problem with regard to establishments located in eastern Germany. There, the earliest data recorded relate to 1991. Some establishments already existed before that year, so the bias in the establishment age becomes more serious. We therefore introduce two dummy indicators, one for an establishment age between 5 and 14 years and a second one for establishments that have been observed for at least 15 years. The reference category is an establishment age of less than 5 years. Because our data set starts in 1998, the reference group contains only eastern German establishments that were founded after 1993, when the ‘dust of reunification’ had settled. Those establishments that already existed before the administrative data were collected are therefore included in the second group with an establishment age of 5-14 years, irrespective of whether they may be older. However, it is fair to argue that the change in the organizational structure and the political system in establishments founded in East Germany prior to reunification were strong enough for the restructured establishment to be regarded as a new firm, irrespective of its ‘true’ age.

In accordance with the theoretical considerations we use the logarithm of the establishment’s revenues as a proxy for expected returns and the current ability to invest in innovation. It also serves as a proxy for establishment size. In the literature review it was argued that greater productivity is related to higher exports and that firms have to innovate in order to be competitive in export markets in the long run. We employ export as a proportion of total sales as another control for such an increase in productivity. The logarithm of the average daily wage paid to workers controls for the cost component. Although wages are assumed to mirror productivity, we expect a negative sign. Consider two 'identical' establishments, which are located in the same region and operate in the same industry and, most importantly, achieve the same level of revenues but pay different wages. Then the establishment which pays higher wages is expected to have higher costs and therefore, the probability of innovation should be smaller. If, however, the estimates are positive, then it is likely that wages capture unobserved and uncontrolled productivity differences. The work by Van Reenen (1996) or Pianta and Tancioni (2008) considers wages in the light of innovation and demonstrates a significant impact that depends on which sector innovates and who is the innovator (i.e. the company under observation or its competitors). Wages increase in firms that perform innovation activity, but they fall if competing firms innovate. Thus innovation activities affect wages in a way that raises concerns regarding reverse causality. We therefore have to accept the limitation and cannot report causal effects but provide evidence of a correlation when wages have a significant effect on innovation behaviour.

From individual observations from the IAB Employment History we compute the following variables. Human capital as a proportion of the total workforce provides a frequently used variable to describe the capacity of the workforce to be innovative. Our measures of human capital follow an advanced approach that takes into account both characteristics of the occupation and formal qualifications. On the basis of a cluster analysis, occupations are classified into low-skilled and high-skilled depending on the average time spent on routine and non-routine work, the average time spent on manual and analytical work and, third, on the proportion of people holding a university degree within this occupation. The classification on the basis of tasks also takes into consideration under- and over-qualification, which has been shown to exist in the German labor market (Brunow and Hirte, 2009). This is described in detail in Trax et al. (2012). The present study differs from the approach used by Trax et al. (2012): we manually reclassify three occupational groups as low-skilled. These are post office workers, clerks and salespersons. The interpretation of high-skilled depends on occupations and formal qualifications. High-skilled occupations are those with a large amount of non-routine and analytical work and a large proportion of graduates.

The work by Ottaviano and Peri (2005) highlights the importance of cultural diversity for production and consumption. The hypothesis is that the presence of many cultures in a region increases, for example, the availability of different skills, country-specific knowledge, various ways of solving problems or, from a consumption point of view, the range of culture-specific products and services (see also Nathan and Lee, 2011). Cultural diversity leads to higher levels of innovation when different cultures interact and combine their culture-specific skills, knowledge and problem-solving abilities, thereby increasing efficiency (Page 2007, Fujita and Weber 2003, Niebuhr 2006, Niebuhr 2010, Ozgen et al. 2011b). However, there can be negative effects as well: language barriers hamper communication and cultural conflicts may also lead to efficiency losses. The net effect can therefore be positive or negative. Because innovation is more likely to be related to human capital, we distinguish between low-skilled and high-skilled when controlling for cultural diversity. In existing literature on cultural diversity the effect is frequently split into two parts: the 'baseline' effect controls for the general presence of foreigners. To this end we include the proportion of foreigners, split into skill groups. The second part considers the distribution of the foreigners employed. We use the fractionalization index for this purpose:

$$Frac = 1 - \sum_{i}^{I} s_i^2,$$

where s_i is the proportion that the ith cultural group constitutes out of I cultural groups employed. This measure is zero if all foreigners belong to the same cultural group and reaches its maximum when all the cultural groups employed are similarly distributed. We again split the measures into the two skill groups. When cultural diversity might be related to different skills and abilities, it is worth separating the effect of the specific knowledge required in distinct jobs from the cultural diversity measures.

We use the occupation data as a proxy for job diversity and construct fractionalization measures on occupational diversity within the low- and high-skilled groups. Although the definitions of the low- and high-skilled groups are based on occupations, the classification does not rely on occupational diversity. Thus, occupational diversity focuses on the distribution of occupations performed within each skill group. If there is a large range of occupations, more specific knowledge from various fields and disciplines is available to the establishment and this could raise the capacity for innovation.

Another form of workforce diversity is associated with age diversity. Mincer's wage equation approach shows how individual productivity changes during the life cycle. Whereas a young employee possesses the latest knowledge, practical work experience increases with age, which raises productivity. However, at the same time, some knowledge becomes obsolete and individual productivity might also decline. If people of different ages interact within a company, high levels of experience can be combined with the latest knowledge, making innovation processes more efficient. We therefore control for age diversity, also on the basis of the fractionalization index. We refrain from using the shares of employed age cohorts because they are highly collinear. Because the special sample from the IAB Employment History does not distinguish between different age cohorts, we use the official Linked Employer-Employee Data, IAB LIAB, to construct this variable. However, this data set does not cover all establishments so the overall data set shrinks.

Two other variables relate to the region and industry and are intended to control for localization economies (Marshall-Arrow-Romer externalities, Glaeser et al. 1992, Combes et al. 2004). Each region corresponds to the NUTS3 level (German districts or ‘Kreise’) and the industry classification is based on the two-digit level of the German Classification of Economic Activities, WZ 2003.

The first variable indicates the number of establishments belonging to the same industry located in the region in which the respective establishment operates. This is intended to control for ‘cluster’ effects within industries (Storper and Venables 2004, Sabel and Piore 2001) as well as for competition effects. Higher levels of competition make it even more important to innovate in order to remain competitive (Geroski 1990, Harris and Trainor 1995). However, a larger number of competitors also increases the likelihood of positive spillover effects. Unfortunately, we cannot separate the spillover effects from competition pressure.

The second variable relates to the proportion of human capital employed within an industry in the region as an alternative measure of the region’s industry-specific knowledge capacity. This proportion is computed excluding the establishment under consideration to avoid collinearity issues. We also tested for other kinds of externality measures as suggested by Combes et al. 2004, but they were found to be insignificant. We therefore keep to the parsimonious model.

5. Estimation issues and results

We aim to explore the number of areas in which individual establishment innovate, i.e. whether an establishment undertakes no innovation, or at least one, two or three types of innovation. We do not distinguish between different combinations of innovation types. Our dependent variable is ordinal and can take the values 0 to 3. Because there is no constant difference between the four outcomes but there is a clear order, the dependent variable is limited dependent. Given the type of data, the ordered logit approach is appropriate and delivers consistent and unbiased estimates. It is a non-linear model and coefficients therefore have to be interpreted with care, but the interpretation of the marginal effects is meaningful.

Although panel analysis controls for unobserved heterogeneity, the average number of observations per establishment, at 2.4, is not sufficient to identify establishment effects. We control for heterogeneity by means of region fixed effects, time fixed effects and industry fixed effects. Region fixed effects control for all unobserved regional factors. It has the advantage, for example, that more productive firms tend to settle in specific regions and less productive firms in others. This selectivity of locational choice will bias the results but the problem is reduced considerably by means of fixed effects, as then firms within one region are considered. Therefore, region fixed effects are favored. A disadvantage of the region fixed effects approach is, however, that variation in regional variables is relatively low and the measures are quite time constant, which then yields insignificant results because of the missing within-region variation.

Different industries have different probabilities of becoming innovative. As was the case with regions, not controlling for industry characteristics would bias the remaining estimates. Finally, time fixed effects control for unobserved shocks in individual years.

All the fixed effects are represented by means of dummy variables. The estimates of the remaining variables as outlined in the previous section are therefore conditional on the fixed effects included. We estimate various models excluding and including fixed effects. The results suggest that omitting fixed effects yields systematic differences in parameter estimates. Moreover, the fixed effects are jointly significant and therefore improve the results. Thus, excluding fixed effects yields biased estimates. If we estimate a model including only the fixed effects and compare this 'constant-only' model with the alternatives that include relevant variables as outlined in the previous section, the additional variables significantly improve the model fit.

Table 2 reports the estimated coefficients of the ordered logit model including region, industry and time fixed effects. Reported standard errors are clustered at the establishment level and are therefore robust against some misspecification issues. We provide four different models including subsets of variables. Including additional variables has virtually no effect on the estimates of the included variables. The only difference in parameters and significance is between models 3 and 4 for the effect of wages, when workforce age diversity is taken into account. Individual skills and experience change over time and should therefore influence individual wages. Taking age diversity into account controls for wage diversity and absorbs the effect from the average wage, which now becomes insignificant and smaller in magnitude. Because model 4 has the strongest explanatory power, this is the preferred model for interpretation. The signs of the coefficients provide a first picture and they clearly seem to be

Table 2: Estimated coefficients on the number of innovative activities

	(1)	(2)	(3)	(4)
log. revenues	0.235***	0.197***	0.197***	0.196***
	(0.01)	(0.01)	(0.01)	(0.01)
log. wage	-0.100**	-0.112***	-0.113***	-0.069
	(0.04)	(0.04)	(0.04)	(0.05)
prop. exports	0.753***	0.716***	0.711***	0.743***
	(0.07)	(0.07)	(0.07)	(0.08)
prop. high-skilled workers	0.570***	0.487***	0.483***	0.481***
	(0.05)	(0.06)	(0.06)	(0.07)
D. sole trader	-0.159***	-0.142***	-0.144***	-0.133***
	(0.03)	(0.03)	(0.03)	(0.04)
D. private partnership	-0.110**	-0.094**	-0.094**	-0.118**
	(0.04)	(0.04)	(0.04)	(0.05)
D. foreign owner	-0.052	-0.056	-0.059	-0.055
	(0.05)	(0.05)	(0.05)	(0.05)
D. establ. age 5-14 yrs.	-0.185***	-0.186***	-0.188***	-0.186***
	(0.04)	(0.04)	(0.04)	(0.04)
D. establ. age 15+ yrs.	-0.262***	-0.272***	-0.271***	-0.259***
	(0.03)	(0.03)	(0.03)	(0.04)
D. new equipment	-0.211***	-0.215***	-0.215***	-0.190***
	(0.03)	(0.03)	(0.03)	(0.03)
D. moderate equipment	-0.430***	-0.439***	-0.438***	-0.402***
	(0.03)	(0.03)	(0.03)	(0.03)
D. oldest equipment	-0.522***	-0.534***	-0.530***	-0.540***
	(0.06)	(0.06)	(0.06)	(0.07)
prop. low-skilled foreigners		-0.250**	-0.246**	-0.262*
		(0.11)	(0.11)	(0.13)
frac. low-skilled foreigners		-0.102*	-0.102*	-0.110*
		(0.05)	(0.05)	(0.06)
prop. high-skilled foreigners		-0.108	-0.100	0.024
		(0.15)	(0.15)	(0.18)
frac. high-skilled foreigners		0.215***	0.209***	0.255***
		(0.07)	(0.07)	(0.08)
frac. low-skill occupations		0.215***	0.217***	0.198***
		(0.05)	(0.05)	(0.06)
frac. high-skill occupations		0.324***	0.313***	0.292***
		(0.06)	(0.06)	(0.06)
frac. age diversity				0.192**
				(0.07)
log. no. competitors			0.057**	0.063**
in region / industry			(0.03)	(0.03)
prop. high-skilled workers			0.144	0.217
in region / industry			(0.16)	(0.18)
region, time, industry FE	yes	yes	yes	yes
cut value 1	2.917***	2.385***	2.643***	3.166***
	(0.23)	(0.24)	(0.27)	(0.30)
cut value 2	4.261***	3.732***	3.989***	4.543***
	(0.23)	(0.24)	(0.27)	(0.30)
cut value 3	6.087***	5.562***	5.820***	6.417***
	(0.23)	(0.24)	(0.27)	(0.31)
pseudo R2	0.098	0.099	0.099	0.108
log-likelihood	-61376	-61312	-61131	-48163
no. obs.	58494	58494	58326	47130
no. establ.	25183	25183	25151	19235

Note: Establishment cluster robust s.e. in (); significant at * 10%, ** 5%, *** 1%;
D.: dummy; prop.: proportion; frac.: fractionalization index

correct. However, they have to be interpreted with caution because they relate to a distribution that describes the likelihood of a firm undertaking no innovation, or one, two or three different types of innovation. A marginal change in the explanatory variables therefore alters the probability of the outcomes. The change can then have the opposite sign to the estimated coefficients presented in Table 2.

Table 3: Average marginal effects for the change in probabilities

	no innovation	innovation in one area	innovation in two areas	innovation in three areas
log. revenues	-0.040***	0.011***	0.020***	0.009***
	(0.00)	(0.00)	(0.00)	(0.00)
log. wage	0.014	-0.004	-0.007	-0.003
	(0.01)	(0.00)	(0.00)	(0.00)
prop. exports	-0.152***	0.043***	0.074***	0.034***
	(0.02)	(0.00)	(0.01)	(0.00)
prop. high-skilled workers	-0.098***	0.028***	0.048***	0.022***
	(0.01)	(0.00)	(0.01)	(0.00)
D. sole trader	0.027***	-0.008***	-0.013***	-0.006***
	(0.01)	(0.00)	(0.00)	(0.00)
D. private partnership	0.024**	-0.007**	-0.012**	-0.005**
	(0.01)	(0.00)	(0.00)	(0.00)
D. foreign owner	0.011	-0.003	-0.005	-0.003
	(0.01)	(0.00)	(0.01)	(0.00)
D. establ. age 5-14 yrs.	0.038***	-0.011***	-0.018***	-0.009***
	(0.01)	(0.00)	(0.00)	(0.00)
D. establ. age 15+ yrs.	0.053***	-0.015***	-0.026***	-0.012***
	(0.01)	(0.00)	(0.00)	(0.00)
D. new equipment	0.039***	-0.011***	-0.019***	-0.009***
	(0.01)	(0.00)	(0.00)	(0.00)
D. moderate equipment	0.082***	-0.023***	-0.040***	-0.019***
	(0.01)	(0.00)	(0.00)	(0.00)
D. oldest equipment	0.110***	-0.031***	-0.054***	-0.025***
	(0.01)	(0.00)	(0.01)	(0.00)
prop. low-skilled foreigners	0.053*	-0.015*	-0.026*	-0.012*
	(0.03)	(0.01)	(0.01)	(0.01)
frac. low-skilled foreigners	0.022*	-0.006*	-0.011*	-0.005*
	(0.01)	(0.00)	(0.01)	(0.00)
prop. high-skilled foreigners	-0.005	0.001	0.002	0.001
	(0.04)	(0.01)	(0.02)	(0.01)
frac. high-skilled foreigners	-0.052***	0.015***	0.025***	0.012***
	(0.02)	(0.00)	(0.01)	(0.00)
frac. low-skill occupations	-0.040***	0.012***	0.020***	0.009***
	(0.01)	(0.00)	(0.01)	(0.00)
frac. high-skill occupations	-0.060***	0.017***	0.029***	0.013***
	(0.01)	(0.00)	(0.01)	(0.00)
frac. age diversity	-0.039**	0.011**	0.019**	0.009**
	(0.02)	(0.00)	(0.01)	(0.00)
log. no. competitors	-0.013**	0.004**	0.006**	0.003**
in region / industry	(0.01)	(0.00)	(0.00)	(0.00)
prop. high-skilled workers	-0.044	0.013	0.022	0.010
in region / industry	(0.04)	(0.01)	(0.02)	(0.01)
prob(at means)	0.529	0.288	0.150	0.033

Table 3 shows the average marginal effects of model 4, where all explanatory variables enter as regressors. We also report the averaged probabilities of each outcome, which is more than 50% for no innovation, 28.8% for at least one of the three types of innovation, 15% for two types of innovation and less than 4% for all three types of innovation.

An increase in revenues leads to a significant increase in the probability of innovating. As found in other empirical work, exports are positively related to innovation processes in establishments. As argued in theoretical literature (e.g. Melitz, 2003), exporting firms have to compete in global markets and therefore have to innovate. A larger proportion of high-skilled employees increase the likelihood of a firm being innovative. For all variables the marginal effect is strongest for implementing two types of innovation.

The other control variables on establishment characteristics show the expected signs. Sole traders and privately managed companies are more likely not to innovate than limited companies, which reflect their risk aversion. The maturing of establishments and their installed machinery reduces the likelihood of being innovative. Therefore the youngest establishments which also operate with the latest technology are the ones that are most innovative in more areas. Once they mature and do not reinvest in newer technologies, the likelihood of innovation decreases. This reflects the product life cycle but, of course, also causes endogeneity issues. Establishments that have previously innovated are likely to invest in the latest technology. Thus, the decision to innovate is related to having up-to-date machinery and this is a problem of intertemporal reverse causality. However, given our short panel structure with respect to the number of observations for each establishment, we are unable to solve this endogeneity issue.

We now turn to the workforce employed and especially to diversity issues. First, it is surprising that establishments with a larger proportion of foreigners among the low-skilled are less likely to be innovative. Also, the diversity of low-skilled is negatively related to innovation activities of establishments. This contradicts the hypothesis of different problem solving abilities fostering innovation. However, the low-skilled group comprises occupations that are associated with manual tasks and a large degree of routine work. For the US Peri and Sparber (2009) also delivered evidence that low-skilled foreigners are more likely to specialize in manual-routine jobs. If we look at our findings in the light of this argument, it provides an explanation for the negative relationship. Even if the definition of low- and high-skilled is based upon task-related measures, the 'within' heterogeneity is still present in both skill groups. Then, a larger proportion of low-skilled foreigners is associated with production units with little or no innovation capacity. Unfortunately, the IAB Establishment Panel contains no information about the field in which the establishment specializes, so we cannot distinguish between production units and other 'mixed' establishments comprising production units and innovation departments. These differences are thus then captured by differences in the workforce structure.

The picture of cultural diversity among the low-skilled is mirrored in the group of high-skilled foreigners. First, the proportion is insignificant, indicating that it does not matter whether foreigners or Germans are employed in the high-skilled segment. However, if the high-skilled foreigners are more diverse, the capacity for innovation increases, which supports the hypothesis that different approaches to problem solving, country-specific knowledge and increased cultural diversity have an impact on the innovation outcome. The marginal effect of high-skilled cultural diversity is strongly negative for performing no innovation and has the strongest effect on implementing two types of innovation. Thus, establishments that employ a diverse highly-skilled foreign workforce are the ones that are relatively more innovative.

Another form of workforce diversity is the diversity of occupations within the workforce. In the German apprenticeship system the training is very detailed and focused. Therefore, a greater level of diversity with respect to occupations measures the (occupation-specific) knowledge available to the establishment. One might argue that greater diversity provides a broader range of knowledge and therefore that innovation is more likely. Our evidence supports this hypothesis, also for the group of low-skilled occupations, although its magnitude is smaller compared to the diversity of highly skilled employees. Again, the interaction of different knowledge from different occupations and thus, disciplines, raises the innovation capacity and the stock of knowledge within the establishment.

A related concept of diversity is age diversity, which serves as a proxy for the experience structure. Whereas young employees possess the 'latest' knowledge, mature employees are more experienced. The interaction of the two groups again broadens of an establishment's knowledge capacity. Unfortunately, we cannot distinguish here between low- and high-skilled employees because the data on the age distribution comes from the IAB LIAB, which cannot be linked with the advanced classification of occupations. However, we still find a positive and significant marginal effect on innovation outcomes. The more diverse the employed workforce becomes in terms of age , the higher the marginal effect for innovating is and the effect is strongest when two different innovation types are performed.

The results obtained on workforce diversity are in line with the argumentation of Griliches' knowledge production function approach. It was argued that workforce diversity measures different kinds of knowledge and therefore increases the knowledge stock. The interaction between workers from different fields within an establishment transfers knowledge more easily, which is an important driver of innovation. It is linked to lower innovation costs, because the overall efficiency increases, not only in the innovation process but also in the establishment itself.

The knowledge production function approach defined by Griliches (1979) also suggests that there are positive spillover effects at regional level on establishments' innovation capacity. The reason for this is that knowledge has the character of a public good to a certain extent and therefore the regional environment should provide additional efficiency gains the higher the knowledge stock is. Such an argument is also put forward in the literature on growth (e.g. Romer 1990, Grossman and Helpman 1995). Most of the regional variation is captured by regional dummy variables. Unfortunately there is little within-region variation, so the majority of the variables tested become insignificant. This does not have to be the case when we consider intra-industry variables. We employ two variables that describe the regional intra-industry environment. The first one is the proportion of human capital employed in all establishments of the respective industry excluding that of the establishment under consideration. Excluding the respective establishment's own contribution in intended to reduce collinearity issues. Surprisingly, the proportion is insignificant, indicating that a larger proportion of human capital employed in all other establishments in the same industry and region and does not yield a greater likelihood of innovating at least in one area.
The number of competitors, however, is highly significant and positive in its magnitude for performing at least one type of innovation. The marginal effect is negative and significant for not innovating. Thus, concentration within an industry induces or forces establishments to innovate. Higher levels of competition and therefore increased market pressure, as well as agglomeration and spillover effects, make establishments more innovative (McCann and Folta 2011). This is also in line with the literature on innovative milieus. On the other hand, establishments that have hardly any competitors are less innovative. There is a rational explanation for this, which is related to monopoly power and a resulting 'no-need-to-innovate' strategy. However, this argument only holds for high transport costs within the industry, which protects the local market; a market-crowding argument that can be found in the New Economic Geography literature.

All the estimates obtained and discussed so far are conditional on the region fixed effects. They serve to reduce problems of selectivity for establishments in specific regions and also control for any unobserved regional characteristics. A classification scheme was developed by the Federal Institute for Research on Building, Urban Affairs and Spatial Development (Bundesinstitut für Bau-, Stadt- und Raumforschung – BBSR) which classifies regions into broader district types. This classification is based upon two criteria: the first one relates to centrality, the second one to population density. A region can be classed as either an agglomeration area, an urbanized area or a rural area. Within an agglomeration, the region can be a core city, a densely populated area, a populated area or a rural area. This classification therefore permits regional heterogeneity with respect to the general location and its population.

Regional heterogeneity is captured by the region fixed effects, with each region belonging to one of the nine groups listed above. In Table 4 we show the probabilities of an establishment performing one or more types of innovation depending on the region. For this purpose we predict the innovation likelihood for each establishment and then calculate the average of the respective probabilities for each regional district type. Because the probabilities for the innovation outcomes are conditional on all explanatory variables, it includes all workforce and establishment characteristics.

Table 4: Average innovation probabilities depending on establishment's location

	No innovation	Innovation in one area	Innovation in two areas	Innovation in three areas
Agglomeration district				
1. Core cities	0.509	0.257	0.179	0.055
2. Densely populated areas	0.512	0.250	0.179	0.058
3. Populated areas	0.500	0.256	0.186	0.059
4. Rural areas	0.582	0.234	0.144	0.040
Urbanized district				
5. Core cities	0.512	0.259	0.176	0.053
6. Populated areas	0.503	0.250	0.186	0.061
7. Rural areas	0.551	0.242	0.160	0.047
Rural district				
8. Densely populated rural areas	0.533	0.247	0.170	0.051
9. Sparsely populated rural areas	0.602	0.226	0.135	0.037

All reported values relate to proportions not performing innovation or performing one, two or three types of innovation.

It can be seen that the average likelihood of not innovating differs between rural areas (55%-60%) and all other areas (about 50%), irrespective of whether the rural area is located in an agglomeration, urbanized or rural district. Interestingly, for the remaining regions the probabilities of innovating do not vary remarkably. Thus, after controlling for a variety of establishment and workforce characteristics, an establishment located in a core city of an agglomerated district, for instance, has almost the same likelihood of performing two distinct types of innovation as an establishment located in a densely populated rural area in a rural district. The innovation capacity of establishments is therefore not necessarily a pure agglomeration aspect. Another implication of this finding is that unobserved heterogeneity which results in locational selectivity of individual establishments is of minor importance. However, as our results suggest, being in a region with a larger number of competitors increases the likelihood of becoming more innovative.

The findings can be summarized as follows. The likelihood of innovating is less than 50% and this probability is virtually unaffected by the location. The only exceptions are establishments in rural regions, which tend to be non-innovative. The variables under consideration show the expected signs and are in line with other existing work. Interestingly, even if the likelihood of innovating in more than one area is relatively low (about 15% for two, and just over 3% for three types of innovation) a marginal change in the explanatory variables leads to the strongest change in the probabilities of being innovative in two areas. Thus, establishments use a combination of innovation activities in order to remain competitive. We provide evidence of the existence of spillover effects. When the number of establishments in an industry increases, the likelihood of being innovative in more areas increases. Consider two establishments A and B. A is located in an agglomerated area within the industry and B is not. As shown in Table 4, the likelihood of performing innovation does not differ substantially between the regions. Establishment A benefits from the external spillover effect, which means that A needs to employ fewer resources that are positively related to innovation outcomes. B does not gain from such a spillover effect and therefore has to increase its own innovation capacity, for instance by employing more human capital. Because the proportion of human capital within the region and industry is insignificant, positive spillovers seem to be related to links between firms and network effects or pure competition pressure.

6. Conclusion

This paper examines the innovation capacity of individual establishments and especially addresses the question of what type of firm is more likely to implement relatively more types of innovation (product introduction, product improvement or adoption of new technologies). Therefore, each establishment can innovate in one, two or three of these areas or not at all.

After controlling for industry- and region-specific effects, establishment characteristics and those of the workforce employed we provide evidence that establishments can benefit from spillover effects emerging at industry level and from workforce diversity. If the workforce employed is more diverse with respect to the availability of different knowledge, measured as the diversity of occupations, the diversity of age cohorts and the diversity of nationalities employed, the innovation capacity increases and thus, innovation becomes more likely. This is in line with the knowledge-production function hypothesis suggested by Griliches (1979). In addition, the more pronounced the diversity of the workforce employed is, the more likely the establishment is to be innovative in more than one area.

With respect to spillover effects, our results suggest that the number of competitors is a driving force for being more innovative but not the proportion of human capital employed in the other establishments in the same industry and region. With the exception of very rural regions, the likelihood of innovating is quite constant such that selectivity in specific, innovative regions is of minor importance. In the light of the spillovers this means that establishments located in a competitive environment require less innovation capacity of their own in order to achieve the same innovation likelihood. This also suggests that regional networks, which are associated with a wider variety of intra-industry products, lead to more innovation activity.

Future research may investigate the resulting combination of innovation outcomes in order to better understand the innovation patterns of establishments. For instance, are establishments in agglomerated regions more likely to innovate in new products and product improvement whereas establishments in other regions are more likely to adopt new technologies?

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