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Creative and science-oriented employees and firm-level innovation

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Abstract

This paper examines the link between innovation and the endowments of creative and science-oriented STEM – Science, Technology, Engineering and Mathematics – workers at the level of the firm and at the city-/regional-level in Germany. It also looks into whether the presence of these two groups of workers has greater benefits for larger cities than smaller locations, thus justifying policies to attract these workers in order to make German cities 'smarter'. The empirical analysis is based on a probit estimation, covering 115,000 firm-level observations between 1998 and 2015. The results highlight that firms that employ creative and STEM workers are more innovative than those that do not. However, the positive connection of creative workers to innovation is limited to the boundaries of the firm, whereas that of STEM workers is as associated to the generation of considerable innovation spillovers. Hence, attracting STEM workers is more likely to end up making German cities smarter than focusing exclusively on creative workers.

Keywords: Innovation, Creative workers, STEM workers, Smart Cities, Spillover, Germany

JEL: D22, J82, R12, J21, J24, R23

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1. Introduction

"Creative, innovative and open-minded... Discover the city of opportunities". Under this slogan, Berlin launched its branding campaign in 2008. The aim of the campaign was to burnish Germany's capital image as a colourful, diverse, and tolerant metropolis, capable of attracting both tourists and, more importantly, entrepreneurs. Creativity and innovativeness were, in this way, put right at the top of Berlin's economic agenda. But Berlin is far from an exception among cities trying to build their economic reputation on creativity: throughout the USA, various "cool city" initiatives have been implemented and the Scottish city Dundee has brandished itself in the same way by setting up a "Cultural Quarter" (Nathan, 2007). Every aspiring *Smart City* seeks to lure a creative class – often by means of improving local amenities and living conditions (Florida, 2004; Partridge, 2010) – in order to become more dynamic, productive, efficient, more competitive, and *smarter*. More creative cities are deemed livelier and hubs of socioeconomic wellbeing and growth. Therefore, creative cities become Smart Cities that offer the best conditions for innovation and economic growth. Hence, creativity, technology and innovation are at the heart of most smart city and urban development strategies (Florida, 2014; Lee and Rodríguez-Pose, 2016).

The link between an open and creative environment, on the one hand, and innovation and economic growth, on the other, is not new and can be traced at least to the work of Jacobs (1969). Creative workers are considered to use knowledge and information – the instruments of creativity – to produce innovation, making innovation the product of creativity and an essential factor of economic growth (Florida, 2004). This is something that has been embraced by decision-makers the world over, who have oftentimes enthusiastically supported the idea that vying for creative workers puts their city on track to become a smart city. Hence, from this perspective, Berlin is following the right steps.

Whereas the idea that creativity and the presence of a creative class lead to innovation and smart cities has been welcomed by politicians, the opinions by researchers are more mixed. Some argue that the creative class just comprises individuals with high skills, whose contribution to the economy was already well-measured by human capital indicators. From this perspective, dynamic local economies are more related to attracting skilled – and not specifically creative and/or bohemian – people (Glaeser, 2005; Markusen, 2006; Nathan, 2007; Marrocu and Paci, 2012). Moreover, it is often difficult to disentangle skill-related from creative effects: the definition of creative occupations tends often to be subjective and includes, in addition to creative people – such as bohemians, artists, and designers, among others – a large number of workers conducting creative activities in science-related jobs, i.e. STEM occupations (Science, Technology, Engineering and Mathematics) which, in general, also hold a high level of skills (Hyde et al., 2008). Hence, a question that has lingered in the literature relates to whether innovation is indeed driven by creative individuals – what Marrocu and Paci (2012) call bohemians – or by highly skilled professionals conducting creative activities in STEM sectors. This is the question that drives this paper: to what extent does the presence of creative workers drive innovation in firms and, consequently, in cities in Germany.

In order to address this question we consider, first, the association between creative and STEM employees and firm-level innovation incentives. This is a relatively new area of research comprising a small number of contributions (e.g. Peri et al. 2015; Siepel et. al. 2016). We extend this approach and, second, focus on potential spillover effects of both groups emerging at the level of industry and region. Third, we contemplate size effects and whether firms become more innovative when they are located in an area with strong positive externalities or a "buzz region". For this purpose we make use of comprehensive data at the local level in Germany and estimate the probability of German firms increasing different types of innovation outcomes – adaptation, introduction and improvement of new products and services, but also process innovation – depending on the characteristics of their workforce and that of the places where they are located.

The study is structured as follows. Section 2 presents the theory as well as the related literature on creativity and innovation. Section 3 introduces the definition of creative and STEM occupations and gives information about the data and variables. A descriptive overview of creative and STEM employment in relation to innovation is provided in Section 4. Section 5 discusses the results of the probit regression estimations, while section 6 presents the main conclusions and policy implications.

2. To what extent do creative workers spur innovation?

According to Griliches (1979), innovative processes require innovation-related inputs such as R&D capital and human capital. These innovation-related inputs are more likely to take place in urban environments and, thus, in Smart Cities for three reasons. First, cities have a higher knowledge intensity in innovation, leading to potentially reduced innovation costs. Second, knowledge has the properties of a public good, meaning that at least part of the research costs are covered by others as long as the "outside" knowledge can be absorbed by the innovator (Cohen and Levinthal, 1990). If such knowledge is limited to urban areas, only local innovators would gain from it. Lastly, meetings and face-to-face contacts make knowledge exchange of vertically-linked firms easier and more frequent (Gertler, 2003; Storper and Venables, 2004). All these reasons generate an urban 'buzz' and localized positive knowledge spillover effects and therefore urban centres offer potentially better conditions to perform all types of innovation.

Innovative processes, moreover, require human capital and creativity. Florida (2004), following Jacobs (1969), puts the emphasis on the presence of a so-called creative class as the main motor of urban innovation. Different types of creative workers influence the innovative capacity of an economy in a number of ways. The *creative core* (e.g. architects, designers, writers, artists) produce new forms or designs in all aspects of life and work. They provide a cultural environment by means of art galleries, operas, theatres, improving the cultural environment and local living conditions. They may also be directly involved in other innovative processes. Creative professionals engage in a creative, problem-solving process which is at the root of firm-level innovation. Empirical evidence highlights that the concentration of this type of creative people in urban areas creates the right environment for innovation (Boschma and Fritsch, 2009; Clifton, 2014; Fritsch and Stuetzer, 2014; Gottschalk and Hamm, 2011).

There is, however, considerable controversy about the definition of a creative worker. According to Glaeser (2005), creatives can be equated to highly skilled individuals. He argues that the creative class theory can be embedded in the human capital theory of economic growth. However, it has become increasingly common to distinguish between creativity as an output in the labour market, and thus related to specific occupations and human skills as an input, purely connected to the levels of educational attainment of the individual (Cunningham and Higgs, 2009; Marrocu and Paci, 2012; Mellander and Florida, 2014).

Taking this division into account, researchers have tried to analyse the economic impact of the presence of a creative class and creative industries. The majority of the analyses have provided a positive link between both phenomena. It has been found that cities with a greater share of creative industries and creative workers generate more innovation (Knudsen et al., 2007; Baskhsi et al., 2008; Bakshi and McVittie, 2009; Lee et al., 2010; Lee and Drever, 2013; Lee and Rodríguez-Pose, 2014a, 2014b); that creativity is associated with higher wages and GDP (Gabe et al., 2007; Moeller and Tubadji, 2009; Wedemeier, 2010; Mellander and Florida, 2011) and with employment growth (Marlet and van Woerkens, 2007; McGranahan and Wojan, 2007; Boschma and Fritsch, 2009; Moeller and Tubadji, 2009; Wedemeier, 2010). Moreover, the presence of a creative class is regarded to lead to greater economic competitiveness and productivity (Huggins and Clifton, 2011; Marrocu and Paci, 2012) and to higher levels of entrepreneurship and new firm formation (Lee et al., 2004; Boschma and Fritsch, 2009; Clifton, 2014; Rodríguez-Pose and Hardy, 2015). However, some studies are less optimistic and question the relationship between creativity and better economic outcomes (e.g. Gottschalk and Hamm, 2011; Fritsch and Stuetzer 2014).

The analysis of the impact of a different type of highly-skilled and creative individuals – the so-called STEM-trained (Science, Technology, Engineering, and Mathematics) workers – on innovation has attracted somewhat less attention than that of the creative class. There is nevertheless an increasing consensus around the idea that the presence of STEM workers in the firm facilitates complex problem-solving (Hyde et al., 2008; Rothwell, 2013). "STEM workers are uniquely capable of generating ideas, innovation, and externalities that benefit productivity" (Peri et al., 2015: 249) and said increases in individual-level productivity are derived from a greater capacity to produce new innovations associated with the hiring and/or presence of STEM graduates and workers (Moretti, 2012; Wright et al., 2017). Greater STEM capacities at the level of the firm drive science- and skill-based innovation (Peri et al.; 2015: 248), boosting, in turn, job growth, wage rates, and competitiveness in international markets. STEM workers also play a key role in improving living conditions in terms of health, education, and environmental issues (Atkinson and Mayo, 2010). Conversely, a lack of supply of

STEM trained individuals is very often considered an important constraint for firms to innovate (Wright et al., 2017: 190).

The empirical verification of the link between the presence of STEM workers and innovation is, however, still relatively limited. Most of this research, however, highlights a positive link between the presence of STEM workers and firm-level innovation. Recent empirical studies making use of US data have been at the forefront of proving this relationship. Winters (2014a), for example, detects that STEM graduates, native and foreign born, significantly increase both innovation – measured by the metropolitan area patent intensity – and wages, even for not-STEM graduates (Winters, 2014b). Policies aiming to attract STEM graduates can have high social benefits. Peri et al. (2014; 2015) investigate the effects of an inflow of foreign STEM workers and show a significant wage increase of college educated natives and, to a smaller but still significant extent, of non-college educated workers. Moreover, it is stressed that the returns of STEM activities are greater in cities, as living in in denser STEM areas increases the probabilities of matching STEM degree holders with STEM occupations (Wright et al., 2017).

Finally, the combination of creative and STEM activities at the level of the firm may be self-reinforcing for innovation, as indicated by Siepel et al. (2016). These authors examine the joint effect of creative and STEM employees by focusing on the revenue and innovation behaviour of UK firms. They provide evidence that mixing creative and STEM workers in a firm generates substantial benefits. Firms that blend artistic – i.e. creative – talent with scientific – i.e. STEM – skills are more likely to introduce radical innovation and, hence, increase productivity and create more employment (Siepel et al., 2016). These benefits are greater, in particular, for smaller firms (Siepel et al., 2016).

However, Siepel et al.'s (2016) research does not consider the geographical dimensions of this type of interaction. It provides little insight about the type of locations where the combination of creative and STEM workers is more likely to bear fruit and does not consider potential spillover effects from the presence of pools of creative and STEM workers. This is precisely the topic covered in this paper, in which it is assumed that Smart Cities, that bring together pools of creative and STEM workers to a much greater extent than other areas can become hotbeds of innovation and economic development (Marrocu and Paci, 2012). The close proximity of people afforded by cities facilitates interactions and spillovers that are at the root of innovation (Knudsen et al. 2007). Lastly, higher shares of creative and STEM workers generate an innovative environment and form the basis for a potential endogenously growing Smart City or region. However, questions remain about how exactly and through which channels the presence of creative and STEM workers affects innovation. In particular, for the case of Germany, many questions in this respect remain unanswered. In the next sections we address the extent to which the presence of a large creative class, combined with the presence or absence of a large STEM population in the cities and regions of Germany, is responsible for innovation and the emergence of Smart cities.

3. Creative and STEM occupations, data and variables

Creative and STEM occupations

A precise classification of creative and non-creative workers is difficult and often subjective. This is why studies on the creative class partly resort to different definitions of who exactly can be considered as creative (e.g. Marrocu and Paci, 2012; McGranahan and Wojan, 2007). Depending on the focus and geographical dimension of a study, more or less precise information on employment by sector – allowing to tailor a more or less precise classification of creativity – may be available. For instance, Faggian et. al. (2013) and Comunian and Faggian (2014) include students in their classification of creatives. In that work detailed data on the individual study subjects is available, covering the potential knowledge, skills and capability attained during the duration of study. However, in a more general setting, such individual specific data is generally unavailable, as in our case. The most common approach is thus to limit the analysis to identifying a specific list of occupations as creative occupations. It is therefore assumed that creative people sort themselves into creative occupations. Florida's definition, for example, is based on major occupational groups and also includes workers which are not particularly creative, such as managers (Florida, 2004). In order to use a more precise definition, the present work follows the DCMS definition of creative occupations (DCMS, 2015; see also Lee and Rodríguez-Pose, 2014a), which is translated into the German equivalent in the German classification of occupations 2010[2] at a 5-digit level. The creative occupations consist of nine

[2] Klassifikation der Berufe 2010 (KldB2010).

subgroups:[3] Advertising and marketing; Architecture; Crafts; Design: Product, graphic and fashion design; Media: Film, TV, video, radio and photography; IT, software and computer services; Publishing; Museums, galleries and libraries; Music, performing and visual arts.

STEM is also frequently defined as a subjective collection of occupations. Hence, and in order to minimise controversy, we make use of the German Federal Employment Agency on STEM occupations. For IT professions there is a slight overlap between creative occupations and STEM. We therefore assign the IT related occupations to STEM as a more detailed occupational list reveals that the majority of IT activity generally relates to science, mathematical and programming-based occupations. Therefore, our list of creative occupations is closer to Marrocu and Paci's (2012) classification, including Bohemians, writers, artists, publishers, and similar occupations. Our STEM activities relate mainly to the technical aspects of innovation.

Data

The empirical analysis is based on two different data resources. The IAB Employment Statistics (IAB-ES) contains administrative data covering all employees subject to social security contributions in Germany. From this source information is derived about employment at the establishment level, including various characteristics of the individuals (gender, age, education, gross wages and occupation). Additionally, the dataset contains general information at plant level, including location at the level of NUTS 3 region, plant age and industry. Based on this information, aggregate data can be calculated about the presence of all creative and STEM employees in the same industry and region to identify potential spillover effects. All representative data from the administrative IAB-ES dataset is gathered at a regional, sector-specific scale. Unfortunately, the IAB-ES does not record civil servants and self-employed. This is problematic, because self-employed are overrepresented in some subgroups of the creative occupations (e.g. Music, performing and visual arts) (Fritsch and Stuetzer, 2014). This implies that potential spillover effects may be biased downward and cannot be properly identified.[4]

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[3] An overview of all creative and STEM occupations can be found in the appendix.
[4] The German Mikrozensus 2016 includes information on self-employed and occupations for the year 2012. About 22% of all creative individuals are self-employed, without dependent employees. In contrast, only 7.7%

To examine the relationship between the creative occupations and innovation, the IAB-ES is linked to the IAB Establishment Panel (IAB-EP),[5] an annual survey of about 16,000 establishments in Germany. The IAB-EP covers information on revenues and export proportions, the legal and organizational form and innovation behaviour, among others. The relevant questions on innovation behaviour and e.g. revenues relate to the previous 12-month period.

As the research question on innovation focuses on establishments generating revenue from sales, the dataset is restricted and excludes the public sector and financial institutions. Moreover, we eliminate 3,971 observations operating in agriculture, forestry and fishing, mining and the private household sector.

For those reasons, 560 observations for establishments with more than 2,000 employees, 1,237 observations in establishments that changed industry classification, and 1,137 observations of establishments relocating across regions during the period of analysis also had to be dropped. The final data set comprises 115,091 observations, covering 38,532 establishments with a varying number of valid observations between innovation types.

Variables

Regarding the response variables, the IAB-EP surveys include information about innovation activity. The analysis concentrates on a) whether a service or product has been improved or further developed (*Improvement*); b) whether an existing service or product has been adapted (*Adaptation*); c) whether a totally new service or product has been introduced (*Introduction*) and; d) whether a process has been developed that improved the production or the supply of services (*Process Innovation*). All questions relate to the previous year, meaning that all IAB-ES information is taken from the year before the survey was conducted and uniquely matched to the IAB-EP. The time period

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of STEM workers are self-employed. There is also limited overlap in the distribution of creative and STEM workers among industries and regions (Bundesländer) (Figure 1). Self-employed creatives have a relatively strong presence in the industry group of "Creative, artistic and entertaining activities" and, regionally, in Berlin. We therefore assume that self-employed creative individuals are more likely to provide a consumption amenity rather than a direct link to innovation within firms. Unfortunately, the Mikrozensus data does not allow constructing variables for our study, as it does not include detailed regional identification numbers and, as it only covers 2012, it provides no panel structure.

[5] The German Community Innovation Survey, collected by the ZEW, provides more detailed information on firms' innovation behaviour. However, it does not include detailed information on employment structure, meaning that it cannot be used for the purpose of this research. We therefore rely on the IAB-EP. Both data sources closely follow the Oslo-Manual.

of the analysis ranges from 1998 to 2015, although there are gaps in years when no data on innovation was recorded.

Data of the focus variables stem from the IAB-ES as these data enable us to construct measures of creative and STEM employees not just at the plant level, but also at the industry and regional level. At the establishment level the focus variables are the two shares of creative and STEM employees on all employees. Within each of the two groups, there are occupations that typically require vocational training and then there are occupations which normally require higher education. The latter group are assigned as specialists and experts. To achieve further insights of the effect of e.g. creative specialists and experts on firm innovation relative to all creative employees, we additionally construct the specialist-expert shares within the group of creative and STEM employees, respectively.

Similar shares are constructed for the level of industry within the region to capture positive spillover effects of creative and STEM workers working for other firms in a given industry. The employment shares take into account the influence of the qualification and occupational groups, but contain no size effects. In a region with a higher stock of companies within the industry, establishments may benefit more from potential spillover effects. To take size effects into account, we consider the log of the number of establishments as well as the proportion of establishments employing creative and/ or STEM workers on all establishments within the industry and region.

In the case of co-location, there may also be potential spillover effects from any other industries located in the region. We therefore construct similar indicators at regional level. These indicators exclude from the estimation the same industry of the considered establishment (see Trax et al., 2015). Co-agglomeration measures of related industries based on input-output tables have been also tested. The results were in most cases insignificant.

Establishments may choose to locate in a region that offers the best opportunities to perform innovation. If, for instance, the establishment expects a higher degree of spillover effects from the presence in a given region of more creative or STEM workers and from the clustering of other establishments in the same industry, it is likely that it

Table 1: Overview of control variables

Variable	Description	Data Source
Fixed Effects by means of dummy variables for…		
… year FE	Annual controls, addressing time correlations	
… region FE	NUTS-3 region FE (German districts/ *Kreise*), accounting for unobserved regional characteristics and location-specific selectivity of establishments in space	IEB-ES
… industry FE	2-digit industry FE take over unobserved industry characteristics (based on WZ 2003)	IEB-ES
Establishment characteristics		
log(revenues)	Log of total turnover, controlling for differences in establishment returns	IAB-EP
Export share	Share of returns achieved outside Germany	IAB-EP
Establishment age	Dummy indicators for establishment age: 0-3 years, 4-10 years, 11 years and older	IAB-ES
Foreign Ownership	Establishment has a foreign owner	IAB-EP
Sole trader	Dummy when the firm is set up as a sole trader (Reference: Capital limited company)	IAB-EP
Private enterprise	Dummy when the firm is wholly privately owned (Reference: Capital limited company)	IAB-EP
Single-Site-Plant	Dummy when the establishment or plant is the only unit of the company (Reference: the establishment is part of a bigger firm)	IAB-EP
State of the art of machinery and equipment	Dummy set for the state of the art of installed machineries and equipment: newest (reference); new; moderate; out-of-date	IAB-EP
Establishment workforce diversity		
Workforce size	Accounting for differences in establishment size and potential economies of scale; dummy set (1-9; 10-49; 50-99; 100-199; 200-399; 400-599; 600-799; 800-999;1000-1499; 1500-1999)	IEB-ES
Share of women	Gender diversity effects	IAB-ES
Share of foreigners	Control for potential cultural aspects on innovative processes	IAB-ES
Employee age composition	The share of young workers (age <25), controlling for human capital fresh out of the educational system, and of prime age workers (age > 54) as a proxy for experience. The reference group are workers between age 25 and 54.	IAB-ES

will chose such a region. Brunow and Miersch (2015) have shown that innovation probabilities differ significantly among regional types. As a means to account for location-related selectivity in space and its emerging source of endogeneity, we use region fixed-effects by means of dummy variables. This reduces the impact of such selectivity on the estimates. A similar argument holds for differences in industries. Industry fixed-effects are therefore also included. The introduction of all these indicators implies that all between-region and between-industry variation should not influence the estimates.

The estimation also contains a number of control variables that may affect plant-level innovation, as presented in Table 1.

4. Creative and STEM occupations in Germany

Table 2 shows the different innovation types, its relative frequencies, and the share of employees within creative and STEM occupations. As can be seen, 41% of all establishments conduct research in product improvement. On average, the workforce of firms that conduct innovation includes, on average, 2.89% creative and 36.9% STEM workers. The table also reveals that the share of both groups is higher, when innovation is performed. About every fourth establishment adopts existing technologies, the introduction of new products is rare, as less than 10% of establishments have introduced product innovations and less than 20% process innovation.

Table 2: Innovation behaviour and employment shares

Innovation type		N[1]	(relative)	share creative employees[2]	share STEM employees[2]
Improvement	no	67,635	(58.9 %)	2.07 %	24.90 %
	yes	47,188	(41.1 %)	2.89 %	36.90 %
Adaptation	no	86,212	(75.1 %)	2.29 %	28.80 %
	yes	28,655	(24.9 %)	2.75 %	32.70 %
Introduction	no	103,712	(90.3 %)	2.34 %	28.80 %
	yes	11,096	(9.7 %)	3.01 %	39.30 %
Process Innovation	no	69,538	(80.2 %)	2.44 %	26.80 %
	yes	17,159	(19.8 %)	3.00 %	38.30 %

Note: [1] Frequencies differ between innovation types because not all questions were surveyed in all years and missing values.
[2] All differences in shares between innovation and no innovation are significant at a 1% level.

Around 42% of all establishments employ neither creative nor STEM workers. Only 6.15% of all establishments change from not employing creative and/or STEM workers to employing workers in these groups (or vice versa) during the period of analysis. Establishments with no STEM or creative workers display significantly lower innovation rates, as presented in Table 3. Therefore, the presence of creative and/or STEM workers represents an important requisite for innovative processes.

Table 3: Innovation shares depending on employment structure

	Employment of creative or STEM workers			
	Yes		No	
	N	innovation share	N	innovation share
Improvement	69,756	49.73 %	45,067	27.74 %
Adaptation	69,772	28.08 %	45,095	20.10 %
Introduction	69,734	12.23 %	45,074	5.70 %
Process Innovation	51,279	25.59 %	35,418	11.40 %

Regarding potential knowledge spillover effects, Table 4 provides a first picture about whether establishments become more innovative when located in an environment with a higher proportion of creative or STEM occupations.

Table 4: Employment shares in industry and region regarding spillover effects

		share creative employees		share STEM employees	
Innovation type		in industry and region	in region	in industry and region	in region
Improvement	no	2.22 %	2.03 %	26.80 %	27.10 %
	yes	2.32 %*	2.08 %*	36.00 %*	27.60 %*
Adaptation	no	2.25 %	2.04 %	30.00 %	27.30 %
	yes	2.30 %°	2.05 %	32.50 %*	27.50 %*
Introduction	no	2.25 %	2.05 %	29.80 %	27.20 %
	yes	2.39 %*	2.05 %	38.40 %*	28.00 %*
Process Innov.	no	2.40 %	2.22 %	28.30 %	27.20 %
	yes	2.54 %*	2.22 %	37.50 %*	27.8 %*

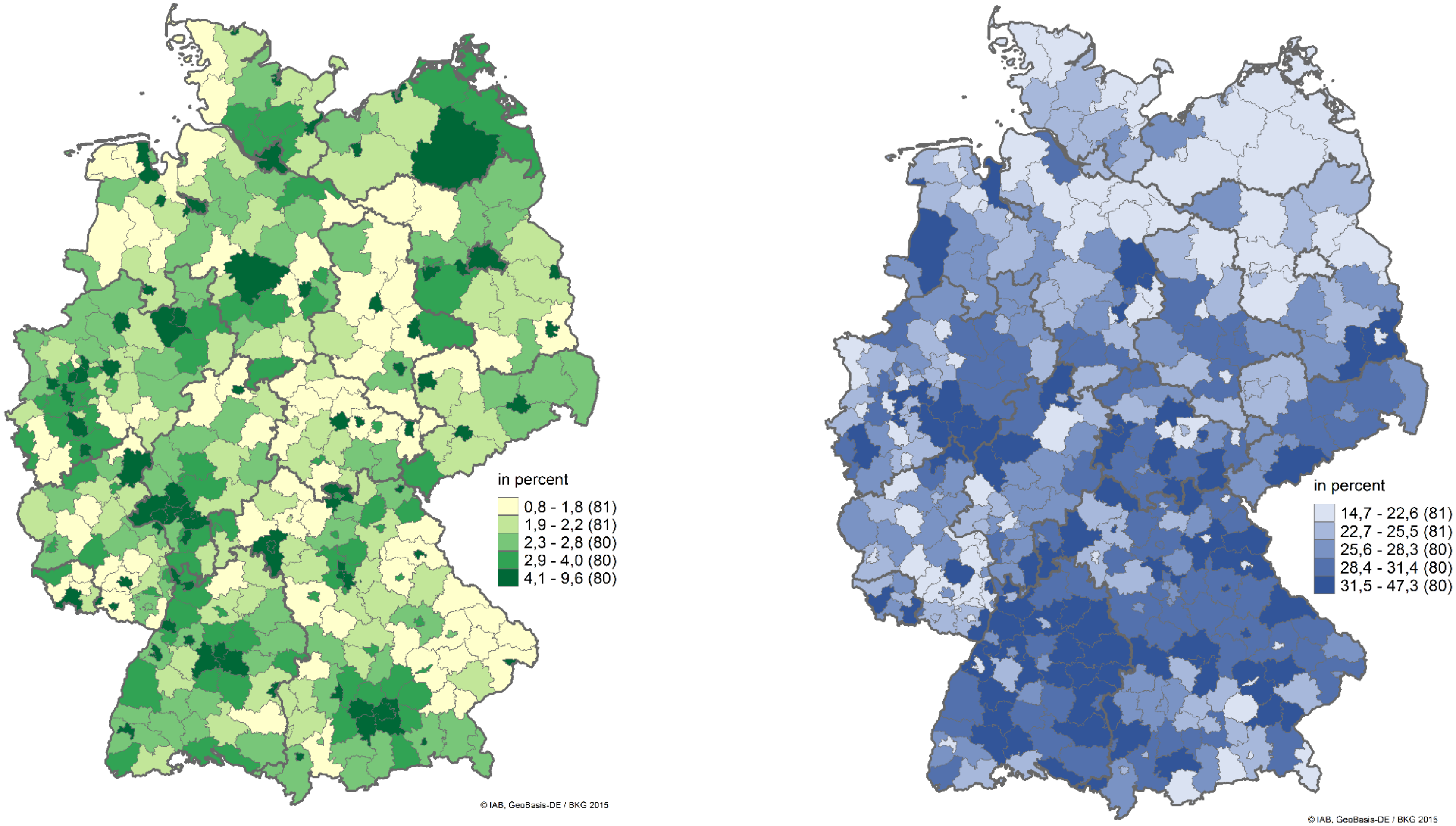
Note: * significant differences in employment shares between innovative and non-innovative establishments at ° 10% level * 1% level

The proportion of creative workers employed within the same industry and region (column 1) and the proportion of creative workers within the same region (over all industries, column 2) is almost identical, although slightly higher for establishments that innovate. In most cases, the differences in shares are statistically different within

Figure 1: Regional distribution of creative and STEM employees on all employees in 2014

a) Creative workers

b) STEM workers



Source: IAB-ES data based on all regional employees in both groups to provide regionally representativeness. BKG Geodatenbasis 2015.

the same region and industry. The difference of employment shares between innovative and non-innovative establishments is more pronounced considering STEM employees of the same industry and region (column 3). There are also differences regarding the overall regional STEM employment shares (column 4), but they are of a smaller magnitude.

Figure 1 maps the regional shares of creative and STEM occupations across German districts at NUTS 3 level. The left figure maps the distribution of creative employees. With few exceptions, creative workers are fundamentally concentrated in cities – where their proportion exceeds 4% of the total workforce. The right figure displays the distribution of STEM workers. This group is much less concentrated in cities than creative workers. STEM workers tend to be located in economically strong regions, such as Bavaria or Baden-Württemberg. By contrast, their presence is much less frequent in predominantly rural regions and/or lagging-behind regions in eastern and northern Germany. Large cities such as Berlin and Munich have a high share of creative workers, but their share of STEM employees is rather low in comparison.

5. Creative and STEM Employment and Innovation

In order to assess the extent to which the presence of creative and STEM workers stimulates innovation across regions in Germany, we make use of a probit model,[6] estimated by maximum likelihood. Standard errors are clustered at the level of industry and region to account for a potential correlation among errors between establishments of the same industry and region or of the same region (Moulton, 1986).

As we expect heterogeneity between manufacturing and service establishments, we interact the focus variables with a dummy for manufacturing establishments. Similar results of the effects of the employment structure within the establishment are found and, as a result, the interaction term is only included for focus variables at higher levels of hierarchy, which are external to the establishment, where heterogeneity matters.

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[6] As the dependent variable is binary and, therefore, can only take the value of 0 or 1.

If establishments decide to become innovative, they may start employing creative or STEM workers. This decision may have not been foreseen when the firm was established. This raises the potential for endogeneity of the focus variables. Because of limitations regarding information on employment strategies, the results of the analyses should be considered as correlations, rather than causal effects.

The left panel of Table 5 presents the results of the relationship between a establishment's share of creative and STEM workers and its incentives to innovate.[7] Following the discussion in the theoretical section, both variables are included independently, as well as in interaction, to test Siepel et al.'s (2016) view about the mutually reinforcing nature of artistic and scientific activities. Both shares of creative and STEM workers are positively associated with innovation, corroborating the results of research in other contexts (e.g. Knudsen et al., 2007; Bakshi et al., 2008; Lee and Rodríguez-Pose, 2014; Peri et al. 2014, 2015; Winters, 2014a). The interaction term is only significant for product improvement innovation, casting doubt about the mutually reinforcing capacity detected for Britain by Siepel et al. (2016) in the case of Germany. However, for all innovation types our results indicate that an increase in the share of specialists and experts among the creative and STEM workers, respectively, is linked to increases in firm-level innovation. These associations apply both to services and manufacturing, although the proportion of STEM workers is, in line with the findings of Brunow and Miersch (2015), less relevant for innovation in manufacturing. In any case, the results are robust and indicate that there is a strong connection between the presence of both creative and STEM employees individually and innovation processes within the firm. These results support Siepel's et. al. (2016) evidence on the positive impact of both groups employed within the firm on firm's innovation behaviour, but not of their combination.

[7] The results of the control variables show the expected signs and are not reported – they can be made available upon request. In any specification all variables are jointly significant. Additionally, region and industry fixed effects, separately, are jointly significant.

Table 5: Establishment-level innovation and creative and STEM workforce

	Innovation in the field of				Innovation in the field of			
	Improvement	Adaptation	Introduction	Process Innov.	Improvement	Adaptation	Introduction	Process Innov.
	Entire Sample (Baseline)				Change in non-employment to employment of creative and/ or STEM workforce or vice versa			
Share creative employees A	0.335***	0.196***	0.187**	0.220***	0.084	-0.088	0.046	-0.127
	(0.063)	(0.062)	(0.079)	(0.083)	(0.161)	(0.153)	(0.190)	(0.198)
Share STEM employees B	0.242***	0.122***	0.110***	0.166***	0.032	-0.049	-0.095	0.047
	(0.027)	(0.026)	(0.032)	(0.033)	(0.073)	(0.075)	(0.102)	(0.102)
Interaction effect A*B	0.861***	0.165	0.395	-0.013	1.034	-0.558	0.912	-1.001
	(0.299)	(0.287)	(0.324)	(0.296)	(1.173)	(1.286)	(1.065)	(2.211)
Share of Specialists and Experts								
… among STEM employees	0.183***	0.132***	0.234***	0.090***	0.125***	0.123**	0.153**	0.095
	(0.024)	(0.023)	(0.026)	(0.028)	(0.048)	(0.049)	(0.068)	(0.059)
… among creative employees	0.177***	0.135***	0.141***	0.067**	0.115	0.188**	0.049	0.116
	(0.031)	(0.028)	(0.033)	(0.033)	(0.090)	(0.081)	(0.113)	(0.105)
Control variables/ FE included	yes	yes	yes	yes	yes	Yes	yes	yes
No of observations	90614	90645	90429	66877	10908	10891	10818	8987
log likelihood	-50754.7	-47231.8	-25523.4	-27385.2	-6243.0	-5382.9	-2450.1	-3177.8
Pseudo R2	0.174	0.079	0.121	0.173	0.100	0.084	0.116	0.110
AIC	102537	95492	52063	55788	12714	10992	5118	6570

Note: Probit regression on innovation outcomes; cluster robust s.e. at the level of industry and region in (), * p<.1; ** p<.05; *** p<.01

The right panel of Table 5 restricts the sample to establishments that started to employ creative or STEM workers during the period of analysis. This means focusing on plants whose strategy has been to employ some workers from one of the two groups with the aim of improving their innovation potential. In this case, only increases in the share of STEM Specialist/ Expert workers are positively associated with innovation. There is less evidence of such a link involving creative workers. The results are robust to the introduction of time-lagged values. Thus, whereas the left-hand panel of Table 5 provides evidence that establishments employing higher shares of both creative and STEM workers are more innovative, the right panel indicates that it is especially the group of STEM specialists and experts that tends to boost innovation. This support the views of those highlighting the relevance of STEM innovation (e.g. Peri et al. 2014, 2015; Winters, 2014a), but puts to the text the validity of the literature on creativity and innovation and firm-level (e.g. Knudsen et al., 2007; Bakshi et al., 2008; Lee and Rodríguez-Pose, 2014) in the case of Germany.

In addition to internal resources for innovative processes, theory suggests that there might be positive spillover effects from the environment in which a firm operates. Table 6 reports the results of spillover variables at the level of industry and region,[8] In Table 6, the left panel displays the estimates for services and the right panel shows the interaction term for manufacturing. First, the coefficients become mostly insignificant, with the exception of the number of intra-industrial establishments in the region in manufacturing. There is no effect for services and manufacturing when the share of establishments employing creative and STEM workers within the industry increases. Thus, only pure size seems to matter in manufacturing, while the presence of MAR externalities also makes a difference. Positive spillover effects of the share of creative and STEM employees also exist, but only for service firms performing process innovation. There is no evidence that higher shares of specialists and experts within the industry and region are associated with higher incentives to innovate. Thus, contrary to the work conducted by Lee and Rodríguez-Pose (2013) and Lee and Drever (2013) for the UK, we find no evidence in Germany for intra-industrial spillover effects, allowing us to make no inferences in relationship to the role of smart cities in this respect.

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[8] We refrain from using such interaction terms of the share of employees in creative and STEM occupations for any higher levels of hierarchy, because of strong multicollinearity.

Table 6: Spillover effects within industry and region

	Innovation in the field of							
	Improvement	Adaptation	Introduction	Process Innov.	Improvement	Adaptation	Introduction	Process Innov.
	Service establishments (reference)				Manufacturing establishments (interaction effect)			
ln(No. of establishments)	0.016	-0.087***	-0.048	-0.079	0.087**	0.133***	0.101**	0.148**
	(0.033)	(0.033)	(0.042)	(0.049)	(0.042)	(0.040)	(0.049)	(0.058)
… among these, share of establishments employing creative and/ or STEM workers	-0.033	0.163	-0.040	-0.374**	0.130	-0.070	0.186	0.623***
	(0.124)	(0.134)	(0.168)	(0.162)	(0.171)	(0.172)	(0.211)	(0.217)
Employment Structure within the industry and region								
… Share creative employees	0.643*	0.176	0.252	0.907*	-0.449	-0.412	0.130	-0.586
	(0.366)	(0.380)	(0.440)	(0.485)	(0.554)	(0.494)	(0.667)	(0.610)
… Share STEM employees	0.250	-0.014	0.089	0.433**	-0.146	-0.128	-0.196	-0.443*
	(0.156)	(0.150)	(0.181)	(0.193)	(0.195)	(0.184)	(0.218)	(0.237)
Share of Specialists and Experts								
… among STEM employees	-0.027	0.052	0.053	-0.027	0.217*	-0.068	0.203	0.085
	(0.059)	(0.059)	(0.077)	(0.074)	(0.121)	(0.114)	(0.134)	(0.142)
… among creative employees	0.032	-0.014	-0.022	-0.028	-0.046	-0.010	-0.023	0.022
	(0.031)	(0.031)	(0.042)	(0.042)	(0.048)	(0.045)	(0.055)	(0.058)

Note: Table 5 continued (Baseline); estimates of manufacturing are interaction effects relative to the respective estimate in services; robust s.e. in (), * p<.1; ** p<.05; *** p<.01

Potential spillover effects may also occur because of the presence of other industries in other sectors and located in the same region. The results of assessing whether this is the case are presented in Table 7 and – with respect to content – they are comparable to the intra-industrial spillover results. However, for adaptation and new product innovation in services, the number of establishments in the region in all other industries becomes positive and significant. We interpret this finding meaning that the presence of a large number of service establishments in other industries represents a kind of intermediate input in the innovation process. This makes new products and the adaptation of existing products necessary to fulfil a firm's customers' needs. It can be that such effect exists especially for knowledge intensive services (KIS). Indeed, for all types of innovation, KIS establishments become more innovative when the number of establishments and thus the relevant market within the region increases. Our results add to existing evidence provided by Lee et al (2010), Knudsen et al. (2007) and Boschma and Fritsch (2009), who all find significant positive results of the degree of regional creativity on innovation. In contrast to these studies, our results explicitly distinguish the creativity within the same and across other industries.

In manufacturing the effect of the number of establishments in the region is still positive for adaptation and introduction, meaning that, for manufacturing, positive spillover exists. Thus, positive innovation incentives appear the greater the number of establishments located in a given region. For services and manufacturing, innovation becomes more likely in areas with greater diversity and more agglomeration of firms, e.g. in Smart Cities.

The results so far provide some first insights about potential spillover effects. We therefore tested for specific effects for subgroups and specifications.[9] First, regarding small and medium-sized enterprises (SMEs), we find not much heterogeneity for services. Considering manufacturing, small firms up to 9 workers do not benefit from intra-industrial concentration, but larger firms – from 10 to 249 workers – do. Firms with 50 to 249 workers are more innovative in improvement and process innovation when the share of establishment employing either creative or STEM workers grows (see Table A.1).

[9] The Tables are not included in the paper but can be provided upon request.

Table 7: Regional spillover effects excluding own industry's contribution

	Innovation in the field of							
	Improve-ment	Adaptation	Intro-duction	Process Innov.	Improve-ment	Adaptation	Intro-duction	Process Innov.
	Service establishments (reference)				Manufacturing establishments (interaction effect)			
ln(No. of establishments)	0.174	0.448***	0.329**	-0.866**	-0.061	-0.097**	-0.090*	-0.170***
	(0.136)	(0.136)	(0.158)	(0.371)	(0.046)	(0.044)	(0.054)	(0.066)
… among these, share of establishments employing creative and/or STEM workers	0.050	0.055**	0.043	0.003	-1.651	-1.560	-2.178	-2.897
	(0.035)	(0.027)	(0.026)	(0.029)	(1.365)	(1.339)	(1.413)	(1.774)
Employment Structure within the industry and region								
Share creative employees	-0.067	0.136	-0.129	0.075	0.082	-0.116	0.102	-0.081
	(0.118)	(0.128)	(0.121)	(0.236)	(0.125)	(0.137)	(0.129)	(0.246)
Share STEM employees	-0.010	0.000	-0.008	-0.015	0.010	0.001	0.005	0.010
	(0.008)	(0.009)	(0.007)	(0.023)	(0.008)	(0.009)	(0.008)	(0.023)
Share of Specialists and Experts								
… among STEM employees	0.770***	-0.428	-0.299	-0.586*	-0.399**	-0.208	-0.034	-0.142
	(0.252)	(0.272)	(0.322)	(0.325)	(0.193)	(0.179)	(0.214)	(0.234)
… among creative employees	-0.029	0.196**	0.002	0.172	-0.038	-0.073	-0.015	-0.148
	(0.094)	(0.090)	(0.110)	(0.106)	(0.083)	(0.080)	(0.098)	(0.097)
Control variables/ FE incl.	yes	Yes	Yes	yes	yes	yes	yes	yes

Note: Table 5 and 6 continued (Baseline); estimates of manufacturing are interaction effects relative to the respective estimate in services; robust s.e. in (), * p<.1; ** p<.05; *** p<.01

Spillover effects may differ between establishments that employ (which we call group A) and those that do not employ creative and/or STEM workers (group B). The results are presented in Table A.2. Considering services first, Group B benefits more than A from the share of establishments that hire creative and STEM workers at the intra-industrial, but also at the regional level regarding innovation. Thus, establishments, that do not have internal resources benefit from external resources whereas the other group has no such effects. The other group A is significantly more innovative (adaptation and introduction) when the share of STEM experts and specialists in the region becomes higher. The estimates of other variables do not provide additional insights. In manufacturing, group B is significantly less likely to be innovative when the share of establishments that employ creative or STEM workers increases within the same industry, but also in all other industries. Thus, in manufacturing the presence of internal resources is important for innovation (Cohen and Levinthal, 1990). There is no significant effect regarding all the other variables.

Region fixed-effects together within little within-region-variation may explain the insignificant results. In contrast to Knudsen et al (2007), who employ population density, we re-estimate the models and include 3 regional type dummy variables instead: agglomerated areas, urban areas and peripheral areas. This classification is provided by the Federal Institute for Research on Building, Urban Affairs and Spatial Development in Germany (BBSR) and assigns regions to one of these groups according to population density and centrality. The advantage of these dummy indicators over population density is that they are based on population density but also take out other unobserved regional heterogeneity within the regional sub-groups. As presented in Table A.3, first, in agglomerated areas the incentives to innovate are highest for service firms. Manufacturing establishments are less likely to be innovative in German metropolitan areas. This can be explained by the fact that most production units are located in urban and peripheral areas and the functions in agglomerated areas might be different. According to Table 6, there is a negative effect of the number of establishments in the same industry in services for the adaptation of innovation. This effect is mainly driven by establishments located in agglomerated and urban regions. The positive effect in manufacturing is due to establishments located in urban and peripheral regions. Additionally, the presence of STEM specialists and experts employed in the same industry yields higher innovation incentives in urban regions. Thus, positive spillover effects in manufacturing emerge in these regions and not necessarily in metropolitan areas. In relationship to Smart Cities, we can conclude that for service establishments located in agglomerations, positive spillovers emerge, whereas for manufacturing spillover effects are mainly present in urban areas. In services the positive effect of all other establishments operating in other industries is driven by establishments located in urbanized areas and partly in peripheral areas (Table 7).

Lastly, the estimations indicate that no spillovers flow from creative industries to other industries and vice versa. None of the coefficients looking at this relationship is significant. Hence, innovation incentives seem to be higher in German cities and, to a lesser extent, in other agglomerated areas. Firms located there in principle benefit relatively more from potential spillover effects. However, this effect hides an important distinction in the contribution of creative and STEM workers to innovation. The proportion of creative employees seems of relatively minor importance for overall innovation, although they play a relevant role for firm-level innovation. Creatives bring in their experience relating to taste and design, which generally stimulates certain types of innovation, but their capacity to generate spillover effects beyond the walls of the firm and spreading to the cities where they live is, at least in the case of Germany, limited. Creative workers help make the buzz of the city and at act magnet for innovative activities (Florida, 2014). But, as our research has shown, in Germany their contribution to general firm-level innovation happens in two types of environments: directly, within the firm and, to a lesser extent, indirectly, by generating the right environment for innovation to take place. By contrast, the role of STEM workers, specialists and experts is more significant for innovation and results in spillover effects (Marrocu and Paci, 2012), especially in urban and partly in rural areas.

6. Conclusions

The aim of this research has been to assess the extent to which a) there is a connection between different types of creative and knowledge-driven environment and firm-level innovation in the case of Germany; b) whether any connection between the presence of creative and STEM workers and innovation is stronger in large cities than elsewhere – underlining the need to make cities smarter. As employment in creative and STEM occupations becomes a more important as a share of the labour market in Germany and elsewhere – and particularly in large urban regions – more questions are being raised about whether training and attracting this sort of workers to urban areas will make cities smarter and more innovative (Florida, 2004). This is particularly important for Germany, as the territorial imbalances in the location of creative and STEM workers are stark. A high share of creative employment in Germany is found in urban regions, with a limited number of smaller cities doing exceptionally well. Moreover, the share of creative employment in East Germany is considerably lower than in West Germany. STEM workers, by contrast, concentrate in richer and more dynamic regions, shunning rural and industrial declining areas in the North and the East of Germany. The transfer of STEM workers from declining to more prosperous regions is a factor behind rising social and economic distress in these areas (Rodríguez-Pose, 2018).

The results of the probit analysis covering more than 115,000 observations at the level of the firm during the period between 1998 and 2015 highlight that, for Germany, innovation is indeed correlated with the share of creative and STEM employment at the firm-level. Firms that employ creative and STEM workers are more innovative than those that do not. This relationship is robust to controlling for regional, sectoral and other establishment related characteristics. However, the role of creative and STEM workers differs significantly outside the walls of the firm. Whereas creative workers only seem to enhance the innovative capacity within the boundaries of the firm, STEM workers – on top of having a stronger overall effect on innovation – are capable of expanding innovation capacity to surrounding areas, both in large urban areas, but also intermediate but prosperous regions (compare Marrocu and Paci, 2012). STEM workers are those more capable of making German cities and towns smarter and more innovative than the groups we have identified as creative workers, who tend to concentrate in the largest cities.

This work represents a first step towards investigating the link between creative and STEM employment and innovation in Germany. Despite the limitations linked to the data, the results provide some indicative policy implications for cities and regions in Germany. For local decision-makers who aim to make their cities and localities smarter and more innovative, the results point that policies as attracting creative and STEM workers are likely to yield important returns in this respect. However, given limited resources, they also indicate that in terms of potential returns, bringing in STEM workers can provide greater value for money in terms of future innovation than focusing exclusively on creative workers: whereas creative workers propel innovation within the firm, making it more a case for individual firms to become concern with their hiring of creativity, STEM workers provide benefits that go well beyond the firm and spillover into neighbouring firms within the same city and/or locality and into surrounding areas. STEM workers are likely to also energise innovation capacities well beyond the main cities and in more intermediate and smaller cities. This makes the case of using public resources to attract STEM workers more justifiable, as they have a greater capacity to make German cities and towns smarter.

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Appendix

Table A.1: Heterogeneity of intra-industrial regional spillovers in SME's

	Innovation in the field of				Innovation in the field of			
	Improve-ment	Adoption	Intro-duction	Process Innov.	Improve-ment	Adoption	Intro-duction	Process Innov.
	Service establishments (reference)				Manufacturing establishments (interaction effect)			
ln(No. of establishments in industry and region)								
...Smallest Enterprises (up to 9 employees)	0.034	-0.086**	-0.032	-0.042	0.009	0.077	0.052	0.082
	(0.038)	(0.037)	(0.050)	(0.053)	(0.051)	(0.049)	(0.062)	(0.069)
...Small Enterprises (10-49 employees)	0.004	-0.079**	-0.042	-0.091*	0.116**	0.148***	0.126**	0.189***
	(0.038)	(0.037)	(0.048)	(0.055)	(0.051)	(0.048)	(0.059)	(0.068)
...Medium sized Enterprises (50-249 employees)	0.008	-0.086**	-0.051	-0.108**	0.124**	0.139***	0.102*	0.144**
	(0.038)	(0.038)	(0.047)	(0.055)	(0.052)	(0.049)	(0.059)	(0.068)
Share of establishments employing creative and/or STEM workers								
...Smallest Enterprises (up to 9 employees)	0.333**	0.294*	-0.047	-0.059	-0.443*	-0.200	0.125	0.284
	(0.153)	(0.160)	(0.206)	(0.197)	(0.227)	(0.231)	(0.312)	(0.310)
...Small Enterprises (10-49 employees)	-0.163	0.150	0.107	-0.461*	0.325	-0.401	-0.098	0.550*
	(0.180)	(0.186)	(0.233)	(0.241)	(0.264)	(0.257)	(0.309)	(0.332)
...Medium sized Enterprises (50-249 employees)	-0.352	0.209	-0.317	-0.886***	0.608**	0.085	0.505	1.345***
	(0.223)	(0.219)	(0.296)	(0.300)	(0.302)	(0.284)	(0.361)	(0.373)
Control variables/ FE incl.	yes	yes	yes	yes	yes	yes	yes	yes

Note: all variables included as in the Baseline modell; estimates of manufacturing are interaction effects relative to the respective estimate in services; robust s.e. in (), * p<.1; ** p<.05; *** p<.01

Table A.2: Spillover effects in firms (not) employing creative and/or STEM workers

	Innovation in the field of				Innovation in the field of			
	Improve-ment	Adoption	Intro-duction	Process Innov.	Improve-ment	Adoption	Intro-duction	Process Innov.
	Service establishments (reference)				Manufacturing establishments (interaction)			
ln(No. of establishments in industry and region)								
… no employment of creative and/or STEM workers	0.024	-0.078**	-0.043	-0.086*	0.075*	0.116***	0.084*	0.159***
	(0.033)	(0.033)	(0.042)	(0.049)	(0.042)	(0.040)	(0.049)	(0.058)
… employment of creative and/or STEM workers	-0.009	-0.113***	-0.060	-0.072	0.189***	0.255***	0.191**	0.158*
	(0.036)	(0.037)	(0.049)	(0.055)	(0.060)	(0.061)	(0.076)	(0.087)
Share of establishments employing creative and/or STEM workers (in industry and region)								
… no employment of creative and/or STEM workers	-0.161	0.082	-0.053	-0.461**	0.311	0.058	0.236	0.755***
	(0.137)	(0.145)	(0.180)	(0.180)	(0.189)	(0.188)	(0.225)	(0.234)
… employment of creative and/or STEM workers	0.331*	0.351*	0.050	-0.146	-0.624**	-0.755**	-0.326	-0.026
	(0.170)	(0.186)	(0.243)	(0.234)	(0.307)	(0.333)	(0.413)	(0.435)
ln(No. of establishments in region excluding own industry)								
… no employment of creative and/or STEM workers	0.199	0.448***	0.372**	-0.857**	-0.085*	-0.095**	-0.088	-0.212***
	(0.136)	(0.136)	(0.158)	(0.370)	(0.048)	(0.046)	(0.055)	(0.067)
… employment of creative and/or STEM workers	0.166	0.475***	0.343**	-0.940**	-0.093	-0.134*	-0.228**	-0.140
	(0.137)	(0.137)	(0.161)	(0.368)	(0.076)	(0.076)	(0.091)	(0.115)
Share of establishments employing creative and/or STEM workers (in the region excluding own industry)								
… no employment of creative and/or STEM workers	-0.033	0.005	0.016	-0.039	-2.728	-1.162	0.396	-4.641**
	(0.037)	(0.032)	(0.033)	(0.035)	(1.828)	(1.708)	(1.787)	(2.214)
… employment of creative and/or STEM workers	0.154***	0.118***	0.080**	0.049	-2.403	-3.209*	-8.664***	-3.485
	(0.036)	(0.034)	(0.040)	(0.041)	(1.926)	(1.937)	(2.763)	(3.142)
Share of STEM experts on all employees in the region excluding the own industry								
… no employment of creative and/or STEM workers	0.541**	-0.557*	-0.410	-0.708**	-0.168	-0.086	0.038	0.052
	(0.269)	(0.286)	(0.338)	(0.341)	(0.221)	(0.207)	(0.245)	(0.270)
… employment of creative and/or STEM workers	1.078***	-0.265	-0.128	-0.419	-0.745*	-0.189	0.296	-1.170**
	(0.267)	(0.287)	(0.350)	(0.351)	(0.432)	(0.433)	(0.579)	(0.585)
Share of creative experts on all employees in the region excluding the own industry								
… no employment of creative and/or STEM workers	-0.033	0.170*	-0.021	0.173	-0.080	-0.079	0.008	-0.184
	(0.105)	(0.102)	(0.125)	(0.119)	(0.100)	(0.096)	(0.120)	(0.116)
… employment of creative and/or STEM workers	-0.029	0.217**	0.015	0.178	0.398**	0.222	-0.209	0.231
	(0.106)	(0.102)	(0.131)	(0.121)	(0.180)	(0.196)	(0.255)	(0.236)
Control variables/ FE incl.	yes	yes	yes	yes	yes	yes	yes	yes

Note: all variables included as in the Baseline modell; estimates of manufacturing are interaction effects relative to the respective estimate in services; robust s.e. in (), * p<.1; ** p<.05; *** p<.01

Table A.3: Spillover effects depending on location in different regional types

	Innovation in the field of				Innovation in the field of			
	Improve-ment	Adoption	Intro-duction	Process Innov.	Improve-ment	Adoption	Intro-duction	Process Innov.
	Service establishments (reference)				Manufacturing establishments (interaction effect)			
agglomeration area	reference				-6.078*	-1.826	-7.346**	-8.579**
					(3.474)	(3.306)	(3.443)	(3.985)
urbanized area	-0.589	-0.790**	-1.014**	-0.060	-2.747	2.064	-4.141	-5.988
	(0.414)	(0.375)	(0.468)	(0.598)	(3.643)	(3.331)	(3.471)	(4.272)
peripherial area	-1.116***	-0.767**	0.014	-0.657	reference			
	(0.387)	(0.365)	(0.467)	(0.504)				
ln(No. of establishments in industry and region)								
...agglomeration area	-0.002	-0.100***	-0.035	-0.027	0.060	0.130***	0.066	0.045
	(0.037)	(0.035)	(0.043)	(0.050)	(0.053)	(0.048)	(0.055)	(0.067)
...urbanized area	-0.031	-0.132***	-0.060	-0.024	0.157***	0.183***	0.094	0.045
	(0.042)	(0.039)	(0.046)	(0.057)	(0.058)	(0.051)	(0.058)	(0.071)
...peripherial area	-0.028	-0.062	-0.075*	-0.020	0.109**	0.105**	0.209***	0.132**
	(0.039)	(0.039)	(0.045)	(0.056)	(0.052)	(0.049)	(0.056)	(0.067)
Share of STEM experts on all employees in the region and own industry								
...agglomeration area	-0.027	-0.016	0.030	-0.114	0.328*	0.073	0.253	0.187
	(0.088)	(0.085)	(0.106)	(0.110)	(0.189)	(0.173)	(0.206)	(0.217)
...urbanized area	-0.135	0.070	0.042	-0.162	0.474**	-0.045	0.417*	0.195
	(0.097)	(0.090)	(0.111)	(0.118)	(0.203)	(0.190)	(0.217)	(0.247)
...peripherial area	-0.146	0.047	0.037	-0.103	0.148	-0.120	0.208	0.287
	(0.089)	(0.087)	(0.110)	(0.120)	(0.184)	(0.171)	(0.214)	(0.219)
ln(No. of establishments in the region excluding the own industry)								
...agglomeration area	-0.015	0.078**	0.020	-0.030	-0.036	-0.107*	-0.065	-0.041
	(0.041)	(0.040)	(0.050)	(0.056)	(0.061)	(0.056)	(0.065)	(0.080)
...urbanized area	0.071	0.170***	0.131**	-0.005	-0.080	-0.126*	-0.067	0.115
	(0.055)	(0.053)	(0.062)	(0.080)	(0.086)	(0.073)	(0.086)	(0.105)
...peripherial area	0.101*	0.123**	0.019	0.037	-0.210***	0.039	-0.147*	-0.112
	(0.052)	(0.050)	(0.063)	(0.075)	(0.075)	(0.069)	(0.087)	(0.094)
Control variables/ FE incl.	yes	yes	yes	yes	yes	yes	yes	yes

Note: all variables included as in the Baseline modell; estimates of manufacturing are interaction effects relative to the respective estimate in services; robust s.e. in (), * p<.1; ** p<.05; *** p<.01