Institute for Employment Research
The Research Institute of the Federal Employment Agency

IAB-Discussion Paper 22/2017

Articles on labour market issues

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ISSN 2195-2663

Innovation and Location in German Knowledge Intensive Business Service firms

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Content

Abstract

Knowledge Intensive Business Services (KIBS) are widely perceived as being important drivers of technological progress and innovation. KIBS are generally understood as depending, driving and thriving on knowledge exchanges and therefore, geographical proximity to markets, customers and suppliers would be expected to be a critical factor in their performance. This paper investigates how the innovation performance and processes of KIBS firms are related to their distance from the nearest city and also to the size of the nearest city. For this purpose we make use of detailed firm level data and consider Germany as a research field. While most current evidence on this topic emerges from Canada, we complements and add to this existing literature on the geography of KIBS by examining these issues in the German spatial setting which largely conforms to a textbook type of spatial urban hierarchy. Our probit results indeed find that there are very strong distance decay and city size effects, and these also vary according to the innovation type.

Zusammenfassung

Wissensintensive unternehmensnahe Dienstleistungsunternehmen (KIBS) entwickelten sich als bedeutende Treiber für technologischen Wandel und Innovationen. Aufgrund der besonderen Arbeitsweise, welche auf Interaktion und Wissensaustausch aufbaut, spielt die räumliche Nähe zu Kunden, Partnern und Anbietern eine bedeutsame Rolle für die Wirtschaftlichkeit und Innovationsfähigkeit von KIBS-Unternehmen. Die vorliegende Arbeit betrachtet das Innovationsverhalten in Abhängigkeit der Distanz zur nächstgelegenen Stadt und unterscheidet hierbei verschiedene Stadtgrößen. Dafür werden detaillierte Daten von deutschen KIBS-Betrieben verwendet. Die Ergebnisse indizieren, dass Distanzeffekte mit der Stadtgröße variieren und für verschiedene Innovationsarten unterschiedlich stark ausgeprägt sind. Insbesondere profitieren KIBS-Betriebe von der Nähe zu anderen Marktteilnehmern und sind besonders innovativ in Zentren. Eine gezielte Förderung von Start-Ups in Zentren erscheint daher sinnvoller als in weniger dicht besiedelten Räumen, in denen das Angebot an wissensintensiven Gütern geringer ist.

JEL-Klassifikation: D22, L84, O31, R12

Keywords: Distance decay, Innovation, KIBS, urban structure

1 Introduction

In recent years there has been growing interest in the geography of Knowledge Intensive Business Services (Muller and Zenker, 2001; Simmie and Strambach, 2006; Polèse and Shearmur 2006; Shearmur and Doloreux 2008; McCann 2007; Doloreux and Shearmur 2012; Shearmur et al. 2016). These firms are widely understood as being important drivers of the modern economy and their location behavior shapes the performance of the localities in which they operate. In this paper we examine the relationships between the location behavior of KIBS firms and their innovation performance within the context of the German economy. In particular we examine the extent to which distances from different types of cities play any role in innovation performance. The spatial structure of the German economy is very different from the cases where these issues have so far been examined, and our aim is to understand whether many of the previously-observed patterns are also evident in this particular spatial context. Our micro-geographic data set is generated from 8,200 postcodes in Germany and covers 7,073 KIBS establishments. We find that indeed, some of the previous findings also emerge in the German context, although simple location-innovation explanations based on the role of urban externalities require much more nuanced interpretations. City size and distance from the city are indeed important innovation influences, but they are not simple or linear relationships, and moreover they also differ for different types of innovations.

The rest of the paper is organized as follows. Section 2 introduces the theoretical background by connecting what is known about innovation in KIBS to the concept of urbanization externalities and this leads us to outline research hypotheses. In Section 3 the data bases, their interconnection and the broad knowledge production function approach we employ are all presented. The descriptive empirical results are provided in Section 4 and then the model based empirical results are reported in Section 5. Section 6 provides a summary and some brief conclusions.

2 The Innovation Geography of KIBS

KIBS are nowadays increasingly seen being major innovators themselves. However, sitting as they often do, somewhere between the manufacturing and traditional service industries, measuring and describing innovation in KIBS is complex (Muller and Doloreux 2009). Indeed, the innovative activities in KIBS are distinct from those in manufacturing firms, in that KIBS are less likely to perform internal research and development activities than their manufacturing counterparts. Instead, their innovativeness is strongly associated with highly qualified employees, constituting internal knowledge resources, collaboration activities with external sources and learning by doing (Freel, 2006; Simmie and Strambach, 2006). As KIBS strongly rely on knowledge as an input factor of innovation, the generation of innovations in KIBS is likely to relatively strongly

depend on interactions or collaboration with external partners as well as on internal resources (Tödtling et al 2006), although this balance depends on the types of innovation being pursued (Amara et al 2009). In general we might expect that for KIBS innovation activities which require a high frequency and intensity of face-to-face knowledge exchanges with suppliers, collaborators or customers, that such firms will be relatively more centrally located with respect to core markets areas than those for which such knowledge interactions are less important or intensive (McCann 2007; Doloreux and Shearmur 2012). However, empirical evidence on spatial innovation patterns and urbanization externalities of KIBS is relatively scarce and, to our knowledge, largely limited to the case of Canada.

In their study on the spatial innovation patterns of KIBS, Doloreux and Shearmur (2012) observe distance based patterns of KIBS innovation for product, process, marketing and management innovation. However, the patterns vary according to the type of innovation, its novelty grade (new to the firm "basic" vs. new to the market "radical") and city sizes. While basic marketing and basic product innovation rise with proximity to a major metropolitan core[1], this is not the case for basic process and basic management innovations. Regarding radical innovations, they find increasing propensities to innovate with distance to major metropolitan cores for process, management and marketing innovation, but for radical product innovations, no spatial patterns are observable. Meanwhile, for distances to small metropolitan areas[2], the innovation results show a different picture. While basic product, process and management innovations tend to decrease with proximity to small metropolitan cores, the propensity for radical process and management innovations increases, although in some cases KIBS firms are more innovative in remote areas than in cities. KIBS innovation effects appear to vary substantially between innovation types and city sizes, although these particular results may also reflect the specific geography of Canada, defined as it is by very large distances between cities and a population which is primarily distributed along a line near the US border.

In this paper we apply these types of arguments to the German polycentric city system where federal state capitals that combine multiple knowledge-related roles are amongst the biggest cities in the country. This is a geography which is fundamentally

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1 According to the setup of the study, metropolitan cores are the central business districts (CBD) of the major metropolitan areas Montreal (3.5m inhabitants), Ottawa-Gatineau (1m inhabitants) and Québec City (0.65m inhabitants).

2 Small metropolitan cores are the CBD of small metropolitan areas, defined as cities that are more than 100km from a major metropolitan area and that have more than 45,000 inhabitants. These are Sherbrooke (183,000 inhabitants), Saguenay (149,000 inhabitants), Trois Rivières (139,000 inhabitants) and Rimouski (46,000 inhabitants).

different to that of Canada, and it may be that in this more regular system-of-cities, which in many ways reasonably well reflects the Christaller-Lösch types of textbook arguments, that the innovation geography of KIBS displays other as yet unobserved features.

3 Data and Model

In order to investigate the innovation geography of German KIBS, we combine data provided by the Institute for Employment Research (IAB) with distance measures derived from a distance matrix based on approximately 8,200 postcodes in Germany. KIBS are identified on a 2-digit level according to NACE Rev. 1.1. including computer and related activities (division 72), research and development (division 73) and other business activities (division 74).

Firm-level dependent variables and control variables are generated combining two data sets of the IAB – namely the IAB Employment Statistics (ES) and the IAB Establishment Panel (EP) – via a unique common establishment identifier.[3] The ES is generated from official German employment statistics and rests on administrative data which is collected by means of the German Social Security system. It covers all employees subject to social security. Thus, self-employed individuals and civil servants are not included in the sample. Via the unique establishment identifier, individual daily employment spells are aggregated on the level of establishments during the entire year. This allows for a detailed description of size and structure of the workforce employed in an establishment. In addition to this information, the ES provides establishment specific data on industry, location (i.e. postcode) and the first occurrence of the establishment number. The other data source – EP – is an annual survey of German plants collected in personal interviews.[4] The sample for the EP is drawn from the population of all German establishments with at least one employee subject to social security and is stratified across both plant size and industries. It provides a wide range of self-reported establishment-specific variables including, among others, innovative activities, turnover and information on the legal form. Regarding firm level data that is generated from ES and EP, the unit of observation is the individual establishment, as opposed to the concept of a firm that could comprise several establishments. This level of observation is particularly suitable for spatial analysis because regional characteristics would be diluted by multi-establishment firms.

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[3] For a detailed description of the combined database and the construction of variables see also Brunow and Blien (2015).

[4] For further information on the IAB establishment panel (EP) see Fischer et al. (2008) and Ellguth et al. (2014).

Distance is modeled using a database on all approximately 8,200 existing postcodes for Germany. For each postal code latitude and longitude of its centroid is calculated. Measurement of distance between centroids is orthodromic and thus based on the spherical law of cosines formula.[5] The distance matrix is applied for the calculation of two distance-based groups of variables. First, each postcode is assigned a spatial feature identifying it as belonging to a specific type of city according to city size. Thus, minimum distances between the postcode of an establishment and the next postcode assigned to a certain type of city can be calculated. Second, the distance matrix is used to model the individual economic environment of each KIBS establishment. By drawing a circle with a predefined radius around the centroid of an establishment postcode we identify all centroids of postcodes within the radius. Using data provided in the ES enables us to calculate diversity and specialization measures for the areas defined. These measures are utilized to include agglomeration externalities due to specialization or diversity of economic structures in our empirical analysis. This circle approach based on postcode information maps the regional economic environment of an individual establishment more precise than regional variables based on NUTS3-regions (German “Kreise” and “Kreisfreie Städte”) as these administrative borders are, to a large degree, arbitrary with respect to economic activity.

From a broad reading of the economic geography and urban economics literatures, and given the data at our disposal, our simple hypothesis is that the innovation probabilities of KIBS will increase not only with proximity to the city, but also according to the size of the city. This hypothesis can be tested using a very general Knowledge Production Function (KPF) approach that relates innovational output to the presence and volume of innovative resources (Griliches 1979) and which has been widely applied as a theoretical basis for innovative processes. It takes the following form:

$$I_{ij} = CON_i^{b1} * ENV_{ir}^{b2} * CIT_i^{b3} * LOC_i^{b4},$$

Where: I_{ij} denotes the innovative output of establishment *i* regarding innovation type *j*; *CON* a vector of control variables including establishment specific internal resources for innovative processes; *ENV* the structure of the economic environment in region *r*; and *CIT* the variables indicating the minimum distance and to the nearest city of establishment *i*. Finally, variable vector *LOC* represents the location of establishment *i* relative to the nearest city. The broad KPF includes both internal and external

[5] d=acos(sin φ1 · sin φ2 + cos φ1 · cos φ2 · cos Δλ) · R, with d=distance, φ=latitude, λ=longitude, R=radius

knowledge resources for innovation, and the KPF for each innovation type is estimated by a probit model.

Table 1 describes innovation types I_j pursued by establishment *i* during the last year. While technological forms of innovation are represented by product improvement and product introduction as well as process innovation, non-technological innovation is indicated by organizational innovation that is a summary variable encompassing various organizational changes.

Table 1
Dependent variables

I = Innovation Type	Scale Level	Description
Product Improvement	Binary	Improvement of product
Product Introduction	Binary	Introduction of a product new to the firm
Process Innovation	Binary	Improvement of process
Organizational Innovation	Binary	Insourcing or outsourcing of services, Restructuring of supplier and customer relationships, Restructuring of competences and responsibilities within the establishment, Introduction of working groups that act independently, Introduction of units with own cost-benefit analysis, Ecological organizational innovation, Improvement of quality management

Explanatory variables

Control variables *CON* in Table 2 reflect various features of a KIBS establishment that might influence their innovative activity. Establishment size is in terms of full-time equivalent employees and productivity is measured as turnover per full-time equivalent employee. In order to control for non-linearities, establishment size is categorized with an establishment size of 20 to 49 employees being the reference category. Human capital is defined as the share of high-skilled employees among the establishment's workforce following a task based definition (Brunow and Blien, 2015). This variable is intended to reflect the firm's internal resources for innovative activities, but to reduce the impact of endogeneity, the variable enters with a one year time-lag. Further control variables consider the legal form of the establishment, its embedment in the company structure and foreign ownership. The age of the establishment (Lee and Rodriguez-Posé 2014) and its capital stock are also controlled for, and time-fixed effects are taken into account by means of annual dummy variables.

Table 2
Independent variables

Variable	Scale Level	Description
CON = Control Variables		
Productivity	Interval	Turnover per employee
Establishment Size	Binary	Categories: 1 to 4, 5 to 9, 10 to 19, 20 to 49 [reference category], 50 to 99, 100 to 149, 150 to 199, 200 to 249, 250 to 499, 500 to 999, 1000 and more employees
Human Capital	Interval	Share of high skilled employees among establishment workforce
Sole Trader	Binary	Legal form of the establishment: Sole trader
Private Company	Binary	Legal form of the establishment: Private company
Limited Liability	Binary	Legal form of the establishment: Limited liability company [reference category]
Single-site Company	Binary	Embedment in company structure: Single-site company [reference category]
Branch Office	Binary	Embedment in company structure: Branch office
Headquarter	Binary	Embedment in company structure: Headquarter
Foreign Ownership	Binary	Establishment is foreign owned
Age: 0-4	Binary	Age of establishment: 0 to 4 years [reference category]
Age: 5-14	Binary	Age of establishment: 5 to 14 years
Age: 15+	Binary	Age of establishment: 15 years and more
Newest Equipment	Binary	Capital stock of the establishment: newest [reference category]
New Equipment	Binary	Capital stock of the establishment: new
Older Equipment	Binary	Capital stock of the establishment: older
Out-of-date Equipment	Binary	Capital stock of the establishment: out-of-date
Time Dummy	Binary	Time dummy variables of each survey year [1999, 2000, 2003, 2006, 2007, 2008, 2009]
ENV = Economic Environment		
Diversity	Interval	Inverse Hirschman-Herfindahl Index of industries; 2-digit-level
Specialization	Interval	Share of employees in own KIBS industry; 2-digit-level
CIT = Distance to nearest City		
Any City	Interval	Minimum distance in 100 km to the next city [50,000 or more inhabitants]
Metropolis	Interval	Minimum distance in 100 km to a Metropolis [500,000 or more inhabitants]
Large City	Interval	Minimum distance in 100 km to a Large City [100,000 to less than 500,000 inhabitants]
Small City	Interval	Minimum distance in 100 km to a Small City [50,000 to less than 100,000 inhabitants]
LOC = Location		
Closest City	Binary	Dummy for the closest city type: Metropolis, Large City, Small City [reference category]

Vector *ENV* is introduced in order to control for potential agglomeration externalities stemming from sectoral economic structures and thus captures potential spillover effects induced by other establishments. It encompasses both measures for specialization and for diversity of economic environments around KIBS establishments. Economic specialization is modeled as share of employees in the own KIBS-industry with respect to overall employment in region *r*. Regional diversity is computed as inverse

Hirschman-Herfindahl Index for region *r*, such that the index augments with rising diversity. Both measures are based on 2-digit industry levels and exclude the contribution of establishment *i* to avoid simultaneity. In general, the local environment covers a radius of 17km around the centroid of the postcode associated with establishment *i*. This radius has been chosen as the average distance between centroids of German NUTS3-regions is about 34km. Thus, the regions modeled for the analysis are comparable to NUTS3-regions in size but do not rest on administrative boarders allowing for a more precise mapping of the local economic environment. In the following, when referring to the term region, we refer to all centroids of postal codes that are in a 17km circle around the centroid of the postal code associated with establishment *i*.

The variables subsumed in vector *CIT* are used to model distance decay effects of knowledge flows and thus urbanization externalities as described in *Section 2*. We differentiate between three city types according to their population size – metropolises with 500,000 or more inhabitants, large cities with 100,000 to less than 500,000 inhabitants and small cities with 50,000 to less than 100,000 inhabitants – and we calculate the minimum distance to each of the city types as well as to any city.

Vector *LOC* is introduced to limit any potential omitted variable bias on the distance decay effects. In order to reduce the types of endogeneity typical in location-agglomeration analyses, we introduce dummy variables that reflect the closest city type. They absorb the between-city-type variation and related potentially differing distance decay patterns between city types. Binary variables “Closest to Metropolis” and “Closest to Large City” are set to one if the location of the establishment is closest to a metropolis or a large city, respectively. Thus, the reference category is being located closest to a small city.

In addition, in order to avoid issues related to intra-city locational differences, we relate the distance of a KIBS establishment to the centroid of the closest postcode area belonging to the respective city. We thus implicitly treat each city as an internally uniform spatial entity, and examine how distance from the city influences the innovation behavior of KIBS.

4 Descriptive Results on the Innovation Geography of KIBS

The total number of KIBS establishments observed in our analysis is 7,073. However, as not each type of innovation has been surveyed each year and because of missing values in the dependent variables, the number of observations varies between 4,264 and 6,199 regarding innovation types. An overview is given in Table 3. 11% of the KIBS establishments in the sample indicate that they have introduced new products or services. Regarding the improvement of products, the share of innovators is substantially higher with 44.8 percent of all KIBS. Nearly one fourth (22.3%) of the KIBS

establishments has improved internal processes. Organizational innovation has been pursued by nearly half (47.4%) of the KIBS establishments. The descriptive statistics of variables and the correlation matrix of control variables can be found in the appendix (Table B.1and Table B2).

Table 3
Innovation types, number of observations and share of innovators

Innovation Type	Number of observations (N)	Share of innovators (%)
Product Improvement	6,199	44.8
Product Introduction	6,189	11.0
Process Innovation	4,264	22.3
Organizational Innova-	4,937	47.4

Source: own calculation

The spatial location of the KIBS establishments in the sample and the city types in Germany are presented in Figure 1. Although, in international comparison, the German city system is quite polycentric due to a relative high degree of federalization of political power, the location pattern of KIBS at first sight not only seems to confirm the tendency of KIBS establishments to locate near or in urban centers but also towards the top of the urban hierarchy: We observe a considerable concentration of KIBS in and around the capital Berlin and the federal state capital Hamburg, which with around 3.5 and 1.7 Million inhabitants are the biggest cities in Germany. The average distance of a KIBS establishment to the next postcode associated with a city with 50.000 or more inhabitants is 8.5 km. Distinguishing between city types reveals that the average distance to a metropolis is about 3.1 km, to a large city slightly more than 9 km and to a small city almost 15 km – always on condition that these city types are the closest city type to a KIBS establishment. The maximum distance to the next city is 91.8 km, which relates to a small city. For metropolises and large cities the maximum distance is around 70 km. Differentiating relative locations of establishments between city sizes in Table 4, shows that 36.1percent of the KIBS establishments in the data used for the empirical analysis are closest to a metropolis. The majority of KIBS (37.3%) are closest to a large city. A further 26.6 percent are closest to a small city. As the ES covers all KIBS in Germany, we are able to compare the locational pattern in our dataset to the overall locational pattern of KIBS in Germany in order to evaluate its locational representativeness. The proportional values for KIBS in Germany show that our dataset slightly over-represents KIBS establishments closest to a metropolis and closest to a large city. However, the deviations are quite small and we thus conclude that the German-wide pattern of KIBS location is represented by our dataset.

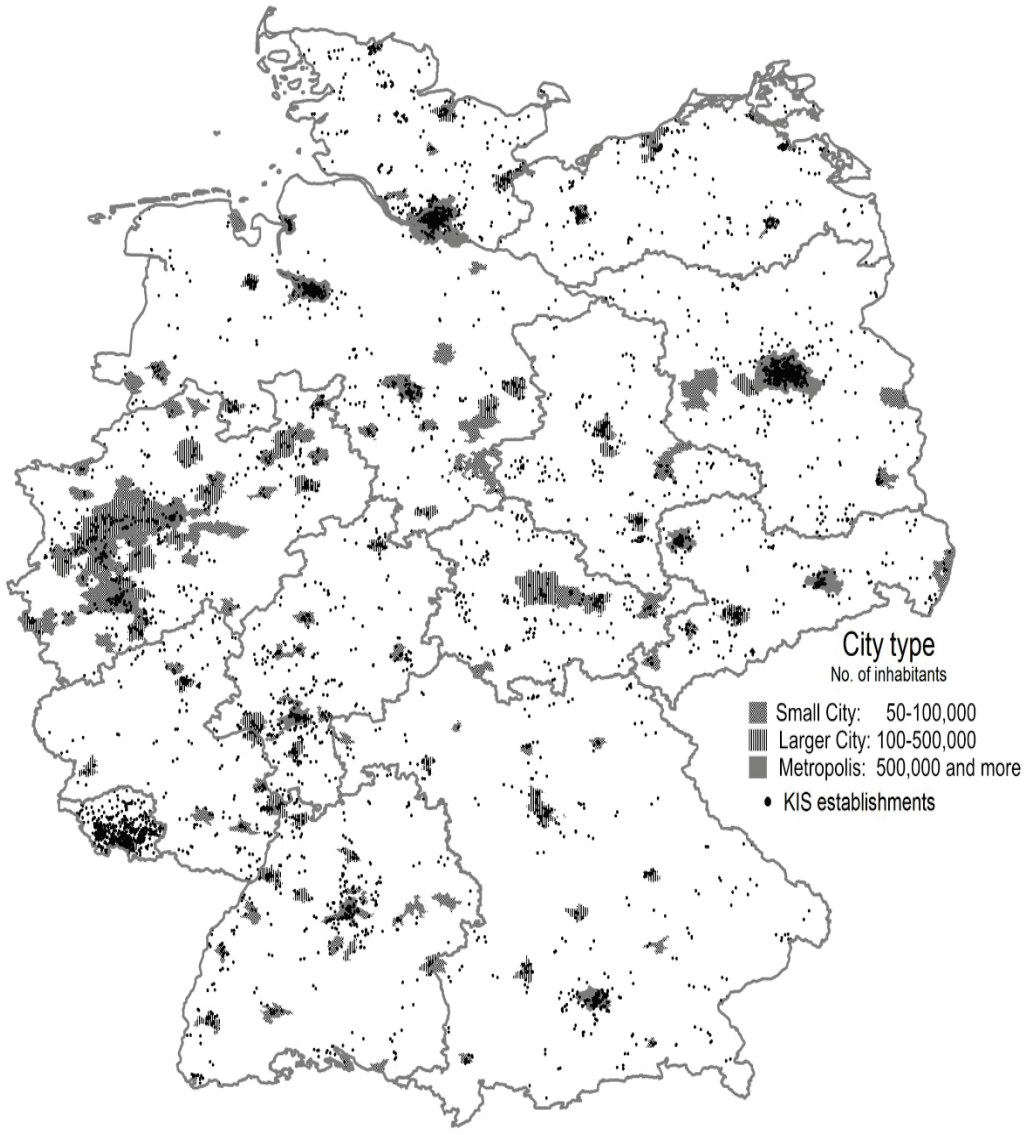
Table 4
Spatial distribution of KIBS establishments depending on closest city type

Closest City Type	Sample	KIBS in Germany*
Closest to Metropolis [%]	36.1	33.4
Closest to Large City [%]	37.3	36.0
Closest to Small City [%]	26.6	30.5
N	7,073	296,154

*Notes: Includes all KIBS with at least one employee subject to social insurance. Calculations are based on averages for the survey years 1999, 2000, 2003, 2006, 2007, 2008 and 2009.

Source: own calculation

Figure 1
Location of KIBS establishments and city types in Germany



Source: Own calculation

In order to gain some first insights on the relationship between innovative activities of KIBS and their spatial location, Table 5 depicts the share of innovators and their respective location separated for the various types of innovation. The locational information captures two things: the closest city type and the distance to the closest city type separated by distance percentiles. We can thus derive two findings for each type of innovation. First, rows indicate differences in innovation behavior in relation to the closest city type. For instance, the first data row reports the share of KIBS establishments that have improved their products and are located within the first percentile of distance to their respective closest city type. The share of establishments that have improved their products in this category varies between 39.1 percent, if they are closest to a large city, and 52.8 percent, if they are closest to a metropolis. Second, columns show how the shares of innovators vary with increasing distance. For example, the column heading “Closest to Metropolis” indicates that the shares of KIBS located closest to a metropolis that have improved their products decrease from 52.8 percent for the first percentile of distance to 27.9 percent for the fourth percentile of distance; i.e. we can observe decreasing shares of establishments that have improved their products with growing distances to metropolises.

Regarding the hierarchy of city sizes, as Table 5 shows, no clear picture emerges. We do not find systematically lower or higher shares of innovators within the same percentile depending on the closest city type. However, there are remarkable distance decay effects for product improvement and organizational innovation. In total, for these innovation types the share of innovators decreases by approximately 15 percentage points with growing distance to cities. There is no such pattern for product innovation and an inverse u-shaped pattern for process innovation. The data also provides first indications that distance decay effects differ depending on the closest city type. On the basis of this descriptive picture we conclude that the distance decay effect is of more importance for innovative activities than the relative location, i.e. the closest city type, but varies between city types.

Table 5
Cross table of KIBS location and innovative activity

Percentiles of distance*	Closest to Metropolis (%)	Closest to Large City (%)	Closest to Small City (%)	Any City (%)
Establishments with Product Improvement				
1	52.8	39.1	48.5	50.6
2	56.3	51.4	44.0	51.8
3	42.5	40.6	47.0	43.3
4	27.9	35.3	34.6	34.3
Total	50.6	42.3	40.9	44.8
N	2,159	2,353	1,687	6,199
Establishments with Product Innovation				
1	11.6	9.8	25.0	11.9
2	10.6	10.3	9.5	10.2
3	10.5	10.3	10.8	10.5
4	10.2	11.3	11.4	11.3
Total	11.1	10.5	11.4	11.0
N	2,156	2,344	1,689	6,189
Establishments with Process Innovation				
1	25.1	23.3	35.9	25.4
2	29.1	27.2	17.6	26.0
3	24.8	18.5	21.9	20.9
4	11.8	19.8	17.4	17.9
Total	25.0	22.0	19.7	22.3
N	1,399	1,634	1,231	4,264
Establishments with Organizational Innovation				
1	54.5	52.4	48.1	54.0
2	51.3	49.1	45.9	49.4
3	45.4	44.7	47.1	45.7
4	46.0	41.7	37.1	39.9
Total	52.2	46.0	42.4	47.4
N	1,850	1,820	1,267	4,937

Notes: * Distances according to percentiles are 0km to 0.87km (1), >0.87km to 1.60km (2), >1.60km to 12.30km (3) and >12.30 (4).

Source: own calculation.

The descriptive examination of the relationship between innovative activities of KIBS and their spatial location indicates, as expected, that there are positive effects of proximity to cities for the innovation probability of KIBS establishments. However, differentiating among innovation and closest city types delivers only the first findings of a complex set of relations between both.

5 Model Estimates on the Innovation Geography of KIBS

In order to validate and to deepen the understanding of these relationships described above, we now estimate the KPF using probit regressions to identify both the effect of location on different types of KIBS innovation in general as well as the effect of city sizes on these types of innovation. In this context, *Model 1* introduces the distance to any city with 50.000 or more inhabitants. The augmented *Model 2* additionally differentiates between the three city types metropolis, large city and small city that represent city sizes according to inhabitants. As we intend to concentrate on the distance

variables, for both models the values of control variables *CON* and variables representing the specialization and diversity of the economic environment *ENV* as well as their average marginal effects (AME) are depicted in the appendix (*Tables C.1*, *C.2*, *C.3* and *C.4*). The results presented in the following are therefore conditional on other explanations such as productivity and employment size at the level of KIBS establishments as well as their economic environment. Also because of the inclusion of location-specific dummy variables *LOC* – i.e. closest to metropolis, large city or small city – we control for endogeneity connected to the locational decisions of KIBS establishments.

In both models presented a joint significance of all variables included is performed and always indicates the joint relevance of these variables. We further test whether the inclusion of the distance related variables *CIT* improves model fit relative to the basic model containing variable vectors *CON*, ENV and *LOC* only. The tests indicate that the inclusion of these variables has explanatory power.

Model 1: Distance decay patterns of innovation for minimum distance to any city

As described, Model 1 aims at identifying general distance decay effects for innovation types related to cities. Distance to any city is defined as distance to the next city with 50.000 or more inhabitants.

Table 6
Results for Model 1 – Distance to any city with 50.000 or more inhabitants

	Product Improvement	Product Introduction	Process Innovation	Organizational Innovation
Distance decay pattern for Any City				
Minimum distance	-2.508***	-0.641	-1.507***	-0.505
	(0.30)	(0.45)	(0.15)	(0.35)
Squared minimum distance	2.243***	0.880**	1.510***	0.491
	(0.35)	(0.43)	(0.48)	(0.50)
Joint significance tests [Chi-Square]				
Distance decay variables	749.8***	88.7***	95.1***	5.6*
All variables	1,085.6***	427.8***	522.2***	742.3***
Model Fit				
Pseudo R2	0.127	0.100	0.115	0.109
N	6,199	6,189	4,264	4,937

***Significant at 1% level, **Significant at 5% level, *Significant at 10% level

Note: Cluster robust s.e. in (), control variables included

Source: own calculation

We allow for non-linear gradients of distance patterns and model distance as minimum distance and squared minimum distance. Because both variables are highly correlated and this correlation is likely to affect significance levels of variables, a joint significance test is performed. As depicted in Table 6 the non-linear distance pattern

is jointly significant for each type of innovation. In probit-regression models, the quantitative interpretation of variable values is somewhat cumbersome as they are only directly interpretable for a latent, i.e. unobservable, dependent variable. Thus, we evaluate the effect of distance to the next city with 50.000 or more inhabitants on innovation probabilities by averaged probability plots. Figure 2 shows that the distance effect on the probability of innovation decreases for all types of innovation with growing distance to the closest city.[6]

With respect to our theoretical reflections the results indicate that proximity to cities matters for innovation and KIBS benefit from urbanization externalities. We conclude that for all types of innovation KIBS establishments can benefit from increased face-to-face interaction and thus the absorption of (tacit) external knowledge that is offered in cities more easily relative to a situation when the KIBS establishment is located rather remote. By incorporating the variable ENV as well as the distance measures, we aimed to distinguish between those influences on KIBS performance and behavior which are location-specific from those which are distance related. As suggested by our theoretical reflections, the sizes of the distance decay effects vary according to the type of innovation pursued by the KIBS establishments – presumably due to different interaction needs connected to innovation types. Comparing the distance decay effects in terms of a percentage reduction of innovation probabilities with increasing minimum distances in the range of 0 to 25 km[7], leads to the conclusion that the strongest distance decay effect of innovation probabilities is observable for product improvement (-32.8%), followed by process innovation (-29.3%), product innovation (-15.5%) and organizational innovation (-7.0%). Compared to the descriptive results in *Section 4.1*, we provide evidence that distance decay effects of product innovation are stronger and distance decay effects of organizational innovation are weaker than one might expect. Thus variables included in the multivariate model substantially change distance decay patterns compared to the purely descriptive results which do not account for further explanations of innovation in KIBS. In general, we conclude from *Model 1* that geographical proximity to a city and interaction with multiple contacts seems of bigger importance for technological types of innovation. However, there might be distinct patterns between city sizes which further explain the observed distance decay effects. These size effects connected to cities are analyzed in *Model 2*.

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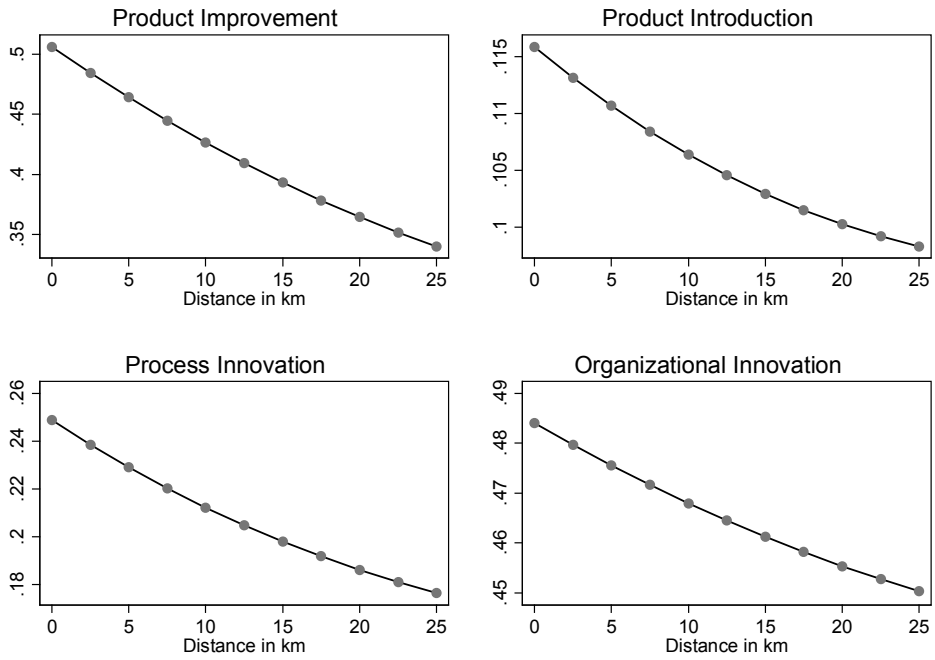
[6] The slope of the probability functions depicted in Figure 2 relates to the Average Marginal Effect (AME) of distance on innovation probabilities.

[7] The threshold of 25 km minimum distance is chosen as it covers 90 % of all KIBS establishments. Differentiating according to the closest city type, it covers more than 95 % of all KIBS establishments located closest to a metropolis, 60 % of those closest to a large city and slightly more than 75 % of those closest to a small city.

Figure 2
Probability of innovation with growing distance to any city



Source: own calculation.

Model 2: Distance decay patterns of innovation for minimum distances to Metropolises, Large Cities and Small Cities

We now introduce *Model 2* that differentiates between city types and depicts distance decay patterns depending on the closest city type, i.e. metropolis, large city and small city. The estimates are presented in Table 7 and are reported without reference category; i.e. they relate to the city specific distance decay functions. As was the case in *Model 1*, in *Model 2* we introduce minimum distance as well as squared minimum distance to control for non-linearity in distance decay patterns and conduct joint significance tests for each pair of distances. Interpretation of distance decay patterns is only feasible if the distance variables are jointly significant. While we find significant results for distance decay patterns of all three city types for product improvement and process innovation, distance effects are only significant for metropolises regarding product introduction and for large cities when organizational innovation is considered. As the estimated differences in slopes between city types might be random, we perform difference in parameter tests to evaluate whether the spatial patterns differ significantly between city types. For process innovation all distance patterns are significantly different from each other. However, regarding product improvement, we find significant differences in the curves of metropolises and large or small cities but not between the curves regarding large and small cities. Thus, metropolises exhibit a different distance decay function than large and small cities. For product introduction

and organizational innovation the difference in parameter tests are of less relevance as in each case we only find significant distance decay patterns for one type of city.

Table 7
Results for Model 2 – Distance decay patterns for Metropolises, Large Cities and Small Cities

	Product Improvement	Product Introduc-	Process Innovation	Organizational Inno-
Distance decay pattern if closest city is a Metropolis				
Minimum distance	-4.948***	-1.577	-3.086***	-0.500
	(1.70)	(1.28)	(0.98)	(0.85)
Squared minimum distance	4.194	0.776	3.056	0.201
	(3.19)	(2.35)	(1.97)	(1.37)
Distance decay pattern if closest city is a Large City				
Minimum distance	-2.818***	0.003	-1.886***	0.217
	(0.51)	(0.60)	(0.28)	(0.58)
Squared minimum distance	4.153***	0.176	3.424**	-0.559
	(1.12)	(0.76)	(1.41)	(1.12)
Distance decay pattern if closest city is a Small City				
Minimum distance	-1.766***	-0.847	-0.963	-1.200**
	(0.56)	(0.89)	(0.76)	(0.55)
Squared minimum distance	1.059	1.277	0.368	1.430**
	(0.78)	(1.02)	(1.43)	(0.66)
Joint significance tests [Chi-Square]				
Distance decay variables for Me-	14,5421.7***	4,900.5***	89.7***	2.5
Distance decay variables for Large	49.2***	0.5	633,361.0***	4,013.3***
Distance decay variables for Small	12.0***	3.3	6.9**	0.3
All variables included	1,112.5***	433.4***	529.0***	745.7***
Difference in parameter tests				
Metropolis vs. Large City	159.1***	256.6***	28.3***	1.6°°
Metropolis vs. Small City	33.4***	20.6***, °°	108.7***	7.2**
Large City vs. Small City	3.5	29.9***, °°	11.7***	3.0°°
Model Fit				
Pseudo R2	0.130	0.101	0.117	0.109
No. obs	6,199	6,189	4,264	4,937

***Significant at 1% level, **Significant at 5% level, *Significant at 10% level

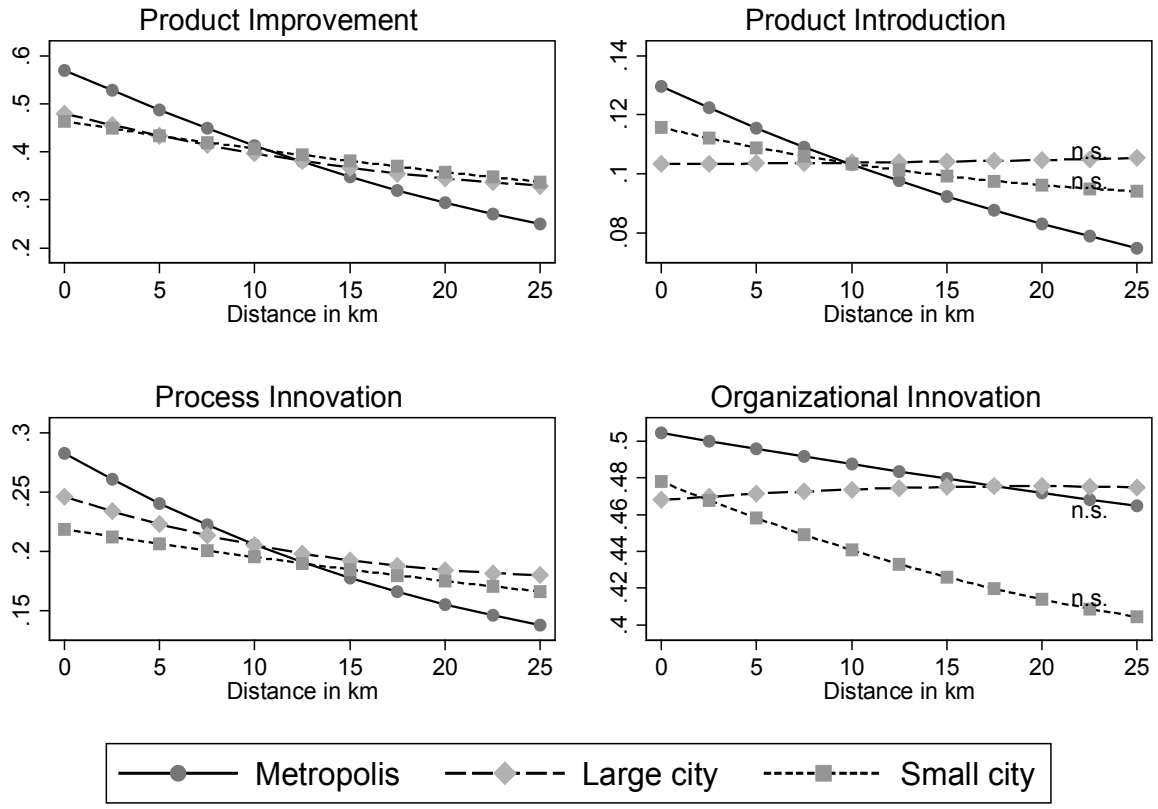
°° Joint significance test for distance decay variables are not significant

Note: Cluster robust s.e. in (), control variables included

Source: own calculation

Again, we illustrate the gradients of innovation probabilities in order to interpret our results, and the curve progressions are depicted in Figure 3.

Figure 3
Probabilities of innovation with growing distances to Metropolises, Large Cities and Small Cities



Note: Average Predicted Probabilities of Model 2; n.s. not significant based on joint significance tests

Source: own calculation

Apparently, given significant distance decay patterns, the distance decay effects differ between city sizes, as we hypothesized. However, as was presented in *Table 8*, the differences are not significant in every case. Table 8 therefore reports the alteration in average probabilities of innovation for 0km and 25km distance to the closest city.

Table 8
Alteration in average innovation probabilities according to city types

	Product Improvement	Product Introduction	Process Innovation	Organizational Innovation
Metropolis	-56.2	-42.3	-51.3	-7.9°°
Large City	-31.2	1.9°°	-26.9	1.5
Small City	-27.2	-18.7°°	-24.1	-15.4°°

Notes: Estimates based on Model 2. Alterations in probabilities for being located 0km and 25km away from the respective city type.

°° Joint significance test for distance decay variables is not significant.

Source: own calculation

For product improvement and for process innovation we find considerable stronger distance decay effects for metropolises than for large and small cities. Relating to the theoretical reflections we draw the conclusion that for these two types of innovation the distance decay effects – i.e. urbanization externalities – are closely connected to city sizes. As large and small cities offer a lower degree of interaction possibilities compared to metropolises, the negative effect of being located further away is weaker. Additionally, most of the metropolises in our analysis do have capital functions which might indicate connections to their qualitative aspects. However, in our analysis we do not explicitly test for these aspects of geography.[8] Due to the flatter shape of the probability curves regarding distances to small and large cities for both types of innovation, we observe a cut value of about 12km where the innovation probability is higher for establishments that are located closest to a small or large city relative to establishments closest to a metropolis. We conclude that the KIBS establishments located closest to a metropolis benefit stronger from proximity and thus rely more on proximate external knowledge resources. On the other hand, establishments located closest to large or small cities rely relatively more on knowledge resources that are not connected to geographical proximity to these types of cities. Put differently, external resources connected to urbanisation as a basis for innovative processes are available to a smaller extent in or close to small and large cities and therefore proximity to these types of cities is less connected to knowledge benefits related to urbanisation.

For product introduction we only find a significant decrease of innovation probabilities with increasing distance to metropolises. Thus, KIBS establishments introducing new products may be located closest to small or large cities and their innovation probability

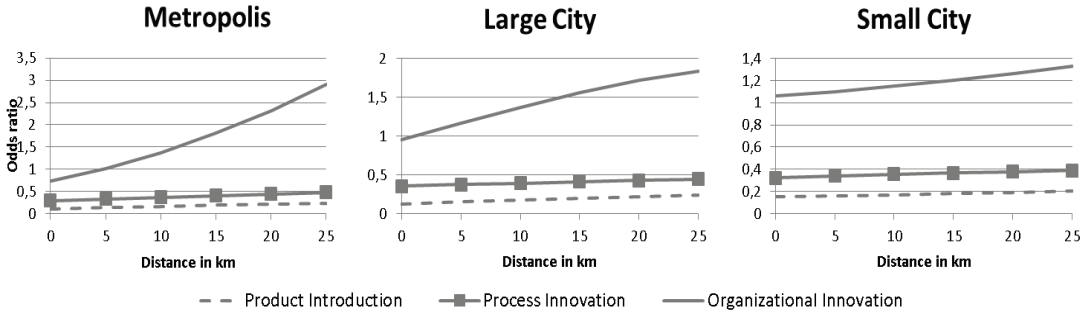
[8] In robustness checks we therefore introduced distances to federal state capitals and the capital city Berlin. These measures always turned out to be insignificant while the results so far remained. This also implies that the distance measure does not serve as a proxy for governmental institutions.

is unaffected by that locational characteristic. Therefore, again, we conclude that establishments that are located closest to large or small cities rather use internal resources or external resources not connected to nearby urbanisation in order to introduce new products rather than external resources provided by the nearest city. In contrast, the sharp decrease in innovation probabilities for KIBS establishments located closes to a metropolis indicates that here, proximity matters and thus interaction connected to spatial proximity is strongly required.

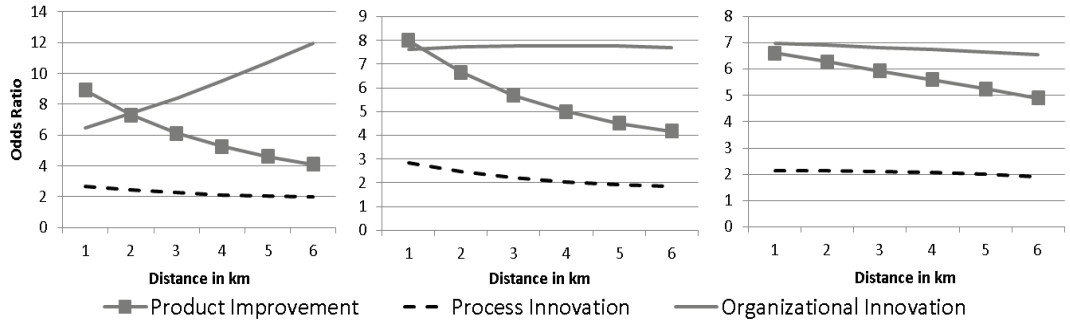
For organizational innovation the distance decay pattern even shows a slight increase of innovation probabilities with growing distance to large cities, while distance patterns in relation to small cities and metropolises are insignificant. This picture is somewhat different to our descriptive findings where the share of innovators decreases with growing distance to all three city types. Therefore, the additional variables included in the probit regressions capture some of the variation between innovative processes and absorb some of the effects from the distance measures.

Figure 4
Relative odds ratios for innovation types according to city sizes

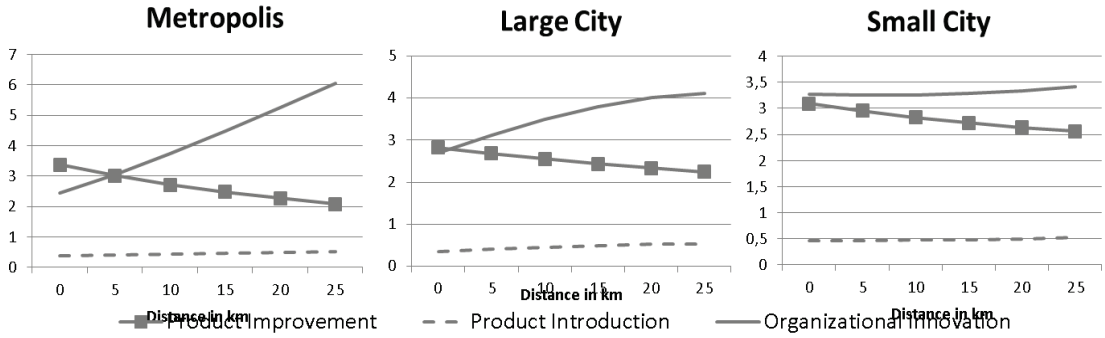
(a) relative to Product Improvement



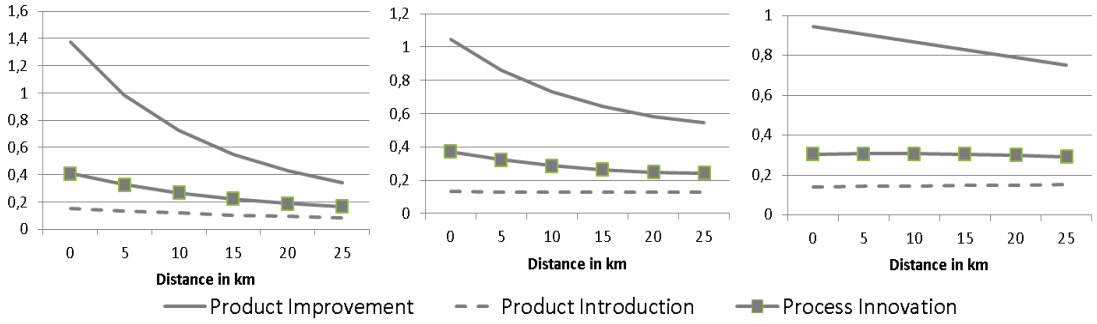
(b) relative to Product Introduction



(c) relative to Process Innovation



(d) relative to Organizational Innovation



Source: own calculation

For some types of innovation there is no significant distance pattern and thus, the probability to innovate is constant irrespective of the distance. Therefore, in these cases the odds are computed on the average predicted probabilities, which are constant in these cases. Figure 4 depicts the relative odds ratios for any two combinations of innovation separated by city types.

For metropolises, we find a concentric pattern between organizational innovation and product improvement. At a distance at around 5 km far apart from a metropolis, the relative odds ratio of organizational innovation on product improvement becomes greater than 1 indicating that organizational innovation becomes relatively more likely. It is worth mentioning that the distance pattern for organizational innovation is independent of distance for metropolises and small cities, as the joint significance tests depicted in Table 8 indicate. Therefore, proximity to the city implying face-to-face contacts is of less relevance for organizational innovation. The effect on the relative odds ratio is driven by the decreasing incentives for product improvement, which obviously depends on proximity to cities and face-to-face contacts, when the establishment is located rather remote. A similar pattern as for metropolises is found for large cities where the relative odds ratio of organizational innovation on product improvement

becomes greater than 1 at around 1 km. This leads to the same implications regarding concentric innovation patterns between those two types of innovations.

6 Summary and Conclusions

In our analysis we have combined three datasets representing internal sources and external resources of innovation as well as micro-geographic data in order to identify the innovation geography of Knowledge Intensive Business Services KIBS across Germany. We analyse innovation distance decay effects associated with increasing distance from cities for four different types of innovations. The empirical results show varying distance decay effects not only connected to the type of innovation pursued by KIBS establishments but also to city sizes. In summary, we find that innovation probabilities decrease considerably with growing distance to metropolises and that decreases in innovation probabilities for distances from large and small cities, if significant, occur to a lesser extent. This conclusion is broadly in accordance with the findings of O'Farrell, Zheng and Wood (1996) and in particular those of Doloreux and Shearmur (2012) who show that firms in less urbanized or more peripheral regions face narrower local knowledge supply bases when conducting innovation. In some cases they may compensate for a narrower local knowledge supply bases by attempting to 'internalize' some of the benefits which are external to those firms in urban regions. As such, even though Germany has a very different spatial structure to Canada, many of the revealed patterns are similar.

However, our results also call for further investigations. First, our city variables relate basically to city size. Yet, cities also vary significantly in terms of other characteristics and more data on these other characteristics put some more flesh on these relationships. Second, the incorporation of supra-local external knowledge resources for innovation in KIBS, e.g. trade fairs, international customers etc., in this type of empirical analysis might add additional explanatory power to our results or even modify some of the distance decay patterns. Third, our modeling does not take into account distances within cities but solely distances to the next postcode with city characteristics, implying that the within-city dynamics of location and innovation do not enter the results. Recent case studies on Milan, Amsterdam and the Jönköping city region indicate that locational patterns of KIBS within cities are not arbitrary but deviate significantly from randomness (Antonietti et al 2013) and might also be connected to their innovativeness (Klaesson and Norman 2015). In the light of our results that indicate strong innovation related distance decay effects between metropolitan and non-metropolitan areas, it would be of interest to consider how intra-urban relationships can be linked to the inter-urban and inter-regional relationships examined here.

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Appendix A: Statistical data on variables

Table A.1
Descriptive statistics of variables

Variable	Mean	Standard Deviation	Minimum	Maximum
I = Innovation Type				
Product Improvement	0.448	0.497	0	1
Product Innovation	0.101	0.313	0	1
Process Innovation	0.223	0.417	0	1
Organizational Innovation	0.474	0.499	0	1
CON = Control Variables				
Productivity [log]	5.589	0.940	-0.379	12.866
Establishment Size: 1 to 4	0.374	0.484	0	1
Establishment Size: 5 to 9	0.126	0.332	0	1
Establishment Size: 10 to 19	0.117	0.322	0	1
Establishment Size: 20 to 49	0.153	0.360	0	1
Establishment Size: 50 to 99	0.096	0.295	0	1
Establishment Size: 100 to 149	0.046	0.208	0	1
Establishment Size: 150 to 199	0.025	0.157	0	1
Establishment Size: 200 to 249	0.017	0.129	0	1
Establishment Size: 250 to 499	0.029	0.167	0	1
Establishment Size: 500 to 999	0.012	0.109	0	1
Establishment Size: 1,000 and m.	0.005	0.069	0	1
Human Capital	0.442	0.403	0	1
Sole Trader	0.283	0.451	0	1
Private Company	0.117	0.321	0	1
Limited Liability	0.600	0.490	0	1
Single-site Company	0.824	0.381	0	1
Branch Office	0.072	0.258	0	1
Headquarter	0.104	0.305	0	1
Foreign Ownership	0.042	0.201	0	1
Age: 0-4	0.187	0.390	0	1
Age: 5-14	0.290	0.454	0	1
Age: 15+	0.523	0.500	0	1
Newest Equipment	0.277	0.447	0	1
New Equipment	0.522	0.500	0	1
Older Equipment	0.186	0.389	0	1
Out-of-date Equipment	0.016	0.124	0	1
ENV = Economic Environment				
Diversity	0.908	0.037	0.426	0.946
Specialization	0.144	0.080	0.000	0.364
CIT = Distance to nearest City				
Any City [100 km]	0.085	0.127	0	0.918
Metropolis [100 km]	0.032	0.082	0	0.741
Large City [100 km]	0.091	0.117	0	0.709
Small City [100 km]	0.149	0.157	0	0.934
LOC = Location				
Closest City Metropolis	0.361	0.480	0	1
Closest City Large City	0.373	0.484	0	1
Closest City Small City	0.266	0.442	0	1

Source: own calculation

Table A.2
Pearson correlation matrix of establishment specific control variables

	Pro-duc-tivity	Estab-lish-ment Size: 1 to 4	Estab-lish-ment Size: 5 to 9	Est. Size: 10 to 19	Est. Size: 20 to 49	Est. Size: 50 to 99	Est. Size: 100 to 149	Est. Size: 150 to 199	Est. Size: 200 to 249	Est. Size: 250 to 499	Est. Size: 500 to 999	Est. Size: 1,000 and more	Hu-man Cap.	Sole Trader	Priv. Comp.	Ltd. Liab.	Single -site Comp.	Br. Office	Head-quar-ter	Fo-reign Own.	Age: 1-4	Age: 5-14	Age: 15+	New-est Equ.	New Equ.	Older Equ.	Out-of-date Equ.
Productivity	1,000																										
Establishment Size: 1 to 4	0,309	1,000																									
Establishment Size: 5 to 9	0,020	-0,303	1,000																								
Establishment Size: 10 to 19	-0,011	-0,297	-0,131	1,000																							
Establishment Size: 20 to 49	-0,116	-0,353	-0,156	-0,153	1,000																						
Establishment Size: 50 to 99	-0,157	-0,255	-0,112	-0,110	-0,131	1,000																					
Establishment Size: 100 to 149	-0,129	-0,172	-0,076	-0,074	-0,089	-0,064	1,000																				
Establishment Size: 150 to 199	-0,115	-0,129	-0,057	-0,056	-0,066	-0,048	-0,032	1,000																			
Establishment Size: 200 to 249	-0,076	-0,096	-0,042	-0,041	-0,049	-0,036	-0,024	-0,018	1,000																		
Establishment Size: 250 to 499	-0,053	-0,144	-0,063	-0,062	-0,074	-0,053	-0,036	-0,027	-0,020	1,000																	
Establishment Size: 500 to 999	-0,098	-0,083	-0,037	-0,036	-0,043	-0,031	-0,021	-0,016	-0,012	-0,017	1,000																
Establishment Size: 1,000 and more	0,025	-0,054	-0,024	-0,023	-0,028	-0,020	-0,014	-0,010	-0,008	-0,011	-0,007	1,000															
Human Capital	0,246	0,034	0,156	0,091	-0,019	-0,107	-0,106	-0,083	-0,045	-0,081	-0,071	0,005	1,000														
Sole Trader	0,067	0,507	-0,025	-0,104	-0,232	-0,180	-0,134	-0,100	-0,065	-0,112	-0,033	-0,042	-0,003	1,000													
Private Company	0,077	0,029	0,031	0,051	0,030	-0,085	-0,013	-0,051	-0,038	-0,057	-0,017	-0,022	0,060	-0,213	1,000												
Limited Liability	-0,110	-0,490	0,004	0,066	0,198	0,219	0,133	0,125	0,084	0,139	0,041	0,052	-0,034	-0,803	-0,411	1,000											
Single-site Company	0,120	0,310	0,087	-0,003	-0,104	-0,179	-0,119	-0,114	-0,107	-0,131	-0,102	-0,102	0,046	0,271	0,068	-0,294	1,000										
Branch Office	-0,035	-0,182	-0,047	-0,003	0,035	0,089	0,103	0,020	0,100	0,108	0,105	0,069	-0,002	-0,150	0,017	0,129	-0,579	1,000									
Headquarter	-0,118	-0,232	-0,069	0,006	0,099	0,147	0,062	0,123	0,051	0,072	0,041	0,069	-0,055	-0,211	-0,096	0,256	-0,756	-0,096	1,000								
Foreign Ownership	0,013	-0,146	-0,057	-0,012	0,035	0,048	0,059	0,148	-0,005	0,140	0,025	0,127	-0,017	-0,134	-0,071	0,168	-0,240	0,015	0,281	1,000							
Age: 1-4	-0,043	0,084	-0,050	-0,055	-0,002	0,032	-0,020	-0,022	-0,005	-0,037	-0,014	-0,014	-0,108	0,015	-0,045	0,013	0,074	-0,012	-0,081	-0,015	1,000						
Age: 5-14	-0,009	0,061	-0,031	-0,028	-0,009	-0,001	-0,042	0,013	0,009	-0,012	0,013	-0,014	0,015	-0,043	-0,045	0,067	-0,011	-0,031	0,038	0,028	-0,342	1,000					
Age: 15+	0,042	-0,124	0,068	0,070	0,010	-0,025	0,055	0,006	-0,004	0,040	-0,001	0,024	0,073	0,028	0,078	-0,074	-0,049	0,039	0,029	-0,015	-0,477	-0,663	1,000				
Newest Equipment	0,025	-0,084	-0,010	0,045	0,009	0,048	-0,006	0,020	0,053	0,024	0,005	0,011	0,077	-0,057	0,000	0,052	-0,022	0,021	0,010	0,017	0,042	-0,035	-0,001	1,000			
New Equipment	0,024	0,001	-0,008	-0,011	-0,018	0,010	0,043	-0,004	-0,032	0,022	0,008	0,003	0,011	-0,003	0,003	0,002	-0,020	0,029	0,001	-0,005	0,001	0,004	-0,005	-0,636	1,000		
Older Equipment	-0,050	0,071	0,033	-0,032	0,015	-0,058	-0,040	-0,019	-0,013	-0,055	-0,012	-0,031	-0,086	0,052	0,003	-0,050	0,040	-0,049	-0,009	-0,010	-0,051	0,039	0,004	-0,287	-0,513	1,000	
Out-of-date Equipment	-0,025	0,065	-0,038	-0,014	-0,007	-0,028	-0,028	0,003	-0,015	-0,002	-0,013	0,047	-0,047	0,048	-0,020	-0,033	0,034	-0,036	-0,013	-0,011	0,006	-0,015	0,009	-0,079	-0,142	-0,064	1,000

Source: own calculation

Appendix B: Additional results of probit regressions

Table B.1
Variable Vectors CON and ENV for Model 1

	Product Improvement	Product Introduction	Process Innovation	Organizational Innovation
CON = Control Variables				
Productivity	0.218***	0.130*	0.181***	0.119***
	(0.01)	(0.07)	(0.00)	(0.02)
Establishment Size: 1 to 4	-0.260***	-0.134**	-0.217***	-0.705***
	(0.04)	(0.06)	(0.06)	(0.00)
Establishment Size: 5 to 9	-0.074**	-0.026	-0.184***	-0.346***
	(0.03)	(0.10)	(0.07)	(0.09)
Establishment Size: 10 to 19	0.076	-0.011	0.074	-0.181***
	(0.08)	(0.02)	(0.07)	(0.02)
Establishment Size: 50 to 99	0.141***	-0.076	0.338***	0.189***
	(0.02)	(0.10)	(0.05)	(0.04)
Establishment Size: 100 to 149	0.399***	0.277***	0.378***	0.281***
	(0.05)	(0.06)	(0.06)	(0.05)
Establishment Size: 150 to 199	0.380***	0.490***	0.548***	0.504***
	(0.11)	(0.13)	(0.05)	(0.10)
Establishment Size: 200 to 249	0.300***	0.411**	0.312***	0.571***
	(0.04)	(0.18)	(0.08)	(0.04)
Establishment Size: 250 to 499	0.414***	0.519***	0.552***	0.433***
	(0.04)	(0.17)	(0.07)	(0.14)
Establishment Size: 500 to 999	0.624***	0.201	0.239***	0.663***
	(0.07)	(0.14)	(0.08)	(0.04)
Establishment Size: 1,000 and m.	1.167***	0.559*	0.931*	0.881***
	(0.08)	(0.31)	(0.53)	(0.17)
Human Capital	0.396***	0.262***	0.221**	0.174**
	(0.09)	(0.05)	(0.09)	(0.08)
Sole Trader	-0.351***	-0.286***	-0.326***	-0.255***
	(0.08)	(0.01)	(0.09)	(0.01)
Private Company	-0.453***	-0.420***	-0.347***	-0.243***
	(0.09)	(0.03)	(0.05)	(0.05)
Branch Office	-0.021	-0.187**	0.127	0.078
	(0.05)	(0.08)	(0.08)	(0.07)
Headquarter	-0.074	-0.168***	0.054	-0.112
	(0.05)	(0.05)	(0.06)	(0.08)
Foreign Ownership	0.064	0.113	-0.024	0.280***
	(0.13)	(0.10)	(0.14)	(0.01)
Age: 5-14	0.014	-0.048	0.021	0.075
	(0.03)	(0.05)	(0.03)	(0.10)
Age: 15+	-0.126***	-0.237***	-0.071**	-0.154
	(0.02)	(0.05)	(0.04)	(0.10)
New Equipment	-0.165***	-0.134***	-0.247***	-0.056***
	(0.02)	(0.05)	(0.02)	(0.00)
Older Equipment	-0.280***	-0.091***	-0.462***	-0.089*
	(0.06)	(0.02)	(0.04)	(0.05)
Out-of-date Equipment	-0.384***	-0.591*	-0.317***	-0.010
	(0.10)	(0.34)	(0.12)	(0.02)
ENV = Economic Environment				
Diversity	0.738	1.846*	-0.704	-1.123***
	(1.22)	(1.11)	(1.04)	(0.17)
Specialization	-3.283***	-3.191***	-2.654***	-0.784
	(1.12)	(0.56)	(0.50)	(0.64)

Notes: Time-fixed effects and locational fixed effects *LOC* included.

***Significant at 1% level, **Significant at 5% level, *Significant at 10% level

Source: own calculation

Table B.2
Variable Vectors CON and ENV for Model 1 – Average Marginal Effects

	Product Improve-ment	Product Intro-duction	Process Inno-vation	Organizational Innovation
CON = Control Variables				
Productivity	0.075***	0.022**	0.048***	0.042***
	(0.00)	(0.01)	(0.00)	(0.01)
Establishment Size: 1 to 4	-0.089***	-0.023**	-0.057***	-0.248***
	(0.02)	(0.01)	(0.02)	(0.00)
Establishment Size: 5 to 9	-0.025**	-0.004	-0.048***	-0.122***
	(0.01)	(0.02)	(0.02)	(0.03)
Establishment Size: 10 to 19	0.026	-0.002	0.019	-0.063***
	(0.03)	(0.00)	(0.02)	(0.01)
Establishment Size: 50 to 99	0.048***	-0.013	0.089***	0.066***
	(0.01)	(0.02)	(0.01)	(0.01)
Establishment Size: 100 to 149	0.136***	0.047***	0.099***	0.099***
	(0.01)	(0.01)	(0.02)	(0.02)
Establishment Size: 150 to 199	0.129***	0.083***	0.144***	0.177***
	(0.03)	(0.02)	(0.02)	(0.04)
Establishment Size: 200 to 249	0.103***	0.070**	0.082***	0.201***
	(0.01)	(0.03)	(0.02)	(0.02)
Establishment Size: 250 to 499	0.141***	0.088***	0.145***	0.152***
	(0.01)	(0.03)	(0.02)	(0.05)
Establishment Size: 500 to 999	0.213***	0.034	0.063***	0.233***
	(0.02)	(0.02)	(0.02)	(0.01)
Establishment Size: 1,000 and m.	0.398***	0.094*	0.244*	0.310***
	(0.02)	(0.06)	(0.14)	(0.06)
Human Capital	0.135***	0.044***	0.058**	0.061**
	(0.03)	(0.01)	(0.02)	(0.03)
Sole Trader	-0.120***	-0.048***	-0.086***	-0.090***
	(0.03)	(0.00)	(0.02)	(0.00)
Private Company	-0.154***	-0.071***	-0.091***	-0.085***
	(0.03)	(0.01)	(0.01)	(0.02)
Branch Office	-0.007	-0.032**	0.033	0.028
	(0.02)	(0.01)	(0.02)	(0.03)
Headquarter	-0.026	-0.029***	0.014	-0.039
	(0.02)	(0.01)	(0.02)	(0.03)
Foreign Ownership	0.025	0.021	-0.004	0.099***
	(0.05)	(0.02)	(0.04)	(0.00)
Age: 5-14	0.005	-0.008	0.005	0.026
	(0.01)	(0.01)	(0.01)	(0.03)
Age: 15+	-0.043***	-0.040***	-0.019**	-0.054
	(0.01)	(0.01)	(0.01)	(0.03)
New Equipment	-0.056***	-0.023***	-0.065***	-0.020***
	(0.01)	(0.01)	(0.00)	(0.00)
Older Equipment	-0.096***	-0.016***	-0.121***	-0.031*
	(0.02)	(0.00)	(0.01)	(0.02)
Out-of-date Equipment	-0.131***	-0.102*	-0.083***	-0.004
	(0.03)	(0.06)	(0.03)	(0.01)
ENV = Economic Environment				
Diversity	0.253	0.314*	-0.185	-0.395***
	(0.42)	(0.20)	(0.27)	(0.06)
Specialization	-1.121***	-0.542***	-0.698***	-0.276
	(0.36)	(0.12)	(0.14)	(0.22)

Notes: Time-fixed effects and locational fixed effects *LOC* included.

***Significant at 1% level, **Significant at 5% level, *Significant at 10% level

Source: own calculation

Table B.3
Variable Vectors CON and ENV for Model 2

	Product Improvement	Product Introduction	Process Innovation	Organizational Innovation
CON = Control Variables				
Productivity	0.214***	0.128*	0.180***	0.119***
	(0.01)	(0.07)	(0.00)	(0.02)
Establishment Size: 1 to 4	-0.249***	-0.130**	-0.211***	-0.706***
	(0.04)	(0.06)	(0.06)	(0.01)
Establishment Size: 5 to 9	-0.059*	-0.018	-0.177**	-0.342***
	(0.03)	(0.11)	(0.07)	(0.09)
Establishment Size: 10 to 19	0.070	-0.013	0.067	-0.182***
	(0.08)	(0.02)	(0.08)	(0.02)
Establishment Size: 50 to 99	0.138***	-0.076	0.334***	0.192***
	(0.02)	(0.11)	(0.05)	(0.04)
Establishment Size: 100 to 149	0.411***	0.287***	0.386***	0.287***
	(0.04)	(0.06)	(0.06)	(0.05)
Establishment Size: 150 to 199	0.375***	0.492***	0.544***	0.514***
	(0.11)	(0.13)	(0.05)	(0.11)
Establishment Size: 200 to 249	0.303***	0.417**	0.318***	0.573***
	(0.04)	(0.18)	(0.09)	(0.04)
Establishment Size: 250 to 499	0.420***	0.527***	0.548***	0.438***
	(0.05)	(0.17)	(0.07)	(0.14)
Establishment Size: 500 to 999	0.613***	0.194	0.229***	0.662***
	(0.07)	(0.14)	(0.08)	(0.03)
Establishment Size: 1,000 and m.	1.167***	0.560*	0.922*	0.882***
	(0.08)	(0.30)	(0.54)	(0.17)
Human Capital	0.400***	0.263***	0.222**	0.176**
	(0.09)	(0.05)	(0.09)	(0.08)
Sole Trader	-0.352***	-0.288***	-0.326***	-0.255***
	(0.08)	(0.01)	(0.09)	(0.01)
Private Company	-0.453***	-0.419***	-0.348***	-0.241***
	(0.09)	(0.04)	(0.04)	(0.05)
Branch Office	-0.018	-0.184**	0.127	0.081
	(0.05)	(0.08)	(0.08)	(0.07)
Headquarter	-0.070	-0.167***	0.056	-0.112
	(0.05)	(0.05)	(0.06)	(0.08)
Foreign Ownership	0.055	0.107	-0.025	0.278***
	(0.13)	(0.10)	(0.13)	(0.01)
Age: 5-14	0.015	-0.050	0.017	0.074
	(0.02)	(0.05)	(0.03)	(0.10)
Age: 15+	-0.130***	-0.240***	-0.074**	-0.154
	(0.02)	(0.06)	(0.04)	(0.10)
New Equipment	-0.170***	-0.131***	-0.247***	-0.054***
	(0.02)	(0.05)	(0.02)	(0.01)
Older Equipment	-0.284***	-0.085***	-0.464***	-0.086*
	(0.07)	(0.02)	(0.04)	(0.05)
Out-of-date Equipment	-0.407***	-0.599*	-0.327***	-0.006
	(0.10)	(0.34)	(0.12)	(0.02)
ENV = Economic Environment				
Diversity	0.717	1.858*	-0.730	-1.154***
	(1.26)	(1.12)	(1.05)	(0.13)
Specialization	-3.399***	-3.222***	-2.703***	-0.763
	(1.06)	(0.59)	(0.49)	(0.64)

Notes: Time-fixed effects and locational fixed effects *LOC* included.

***Significant at 1% level, **Significant at 5% level, *Significant at 10% level

Source: own calculation

Table B.4
Variable Vectors CON and ENV for Model 2– Average Marginal Effects

	Product Improvement	Product Introduction	Process Innovation	Organizational Innovation
CON = Control Variables				
Productivity	0.073***	0.022**	0.047***	0.042***
	(0.00)	(0.01)	(0.00)	(0.01)
Establishment Size: 1 to 4	-0.085***	-0.022**	-0.055***	-0.248***
	(0.01)	(0.01)	(0.02)	(0.00)
Establishment Size: 5 to 9	-0.020*	-0.003	-0.047**	-0.120***
	(0.01)	(0.02)	(0.02)	(0.03)
Establishment Size: 10 to 19	0.024	-0.002	0.018	-0.064***
	(0.03)	(0.00)	(0.02)	(0.01)
Establishment Size: 50 to 99	0.047***	-0.013	0.088***	0.067***
	(0.01)	(0.02)	(0.01)	(0.01)
Establishment Size: 100 to 149	0.140***	0.049***	0.101***	0.101***
	(0.01)	(0.01)	(0.02)	(0.02)
Establishment Size: 150 to 199	0.128***	0.083***	0.143***	0.181***
	(0.04)	(0.02)	(0.01)	(0.04)
Establishment Size: 200 to 249	0.103***	0.071**	0.083***	0.202***
	(0.01)	(0.03)	(0.02)	(0.02)
Establishment Size: 250 to 499	0.143***	0.089***	0.144***	0.154***
	(0.01)	(0.02)	(0.02)	(0.05)
Establishment Size: 500 to 999	0.209***	0.033	0.060***	0.233***
	(0.02)	(0.02)	(0.02)	(0.01)
Establishment Size: 1,000 and m.	0.397***	0.095*	0.242*	0.310***
	(0.02)	(0.05)	(0.14)	(0.06)
Human Capital	0.136***	0.045***	0.058**	0.062**
	(0.03)	(0.01)	(0.02)	(0.03)
Sole Trader	-0.120***	-0.049***	-0.086***	-0.090***
	(0.03)	(0.00)	(0.02)	(0.00)
Private Company	-0.154***	-0.071***	-0.091***	-0.085***
	(0.03)	(0.01)	(0.01)	(0.02)
Branch Office	-0.006	-0.031**	0.033	0.028
	(0.02)	(0.02)	(0.02)	(0.03)
Headquarter	-0.024	-0.028***	0.015	-0.040
	(0.02)	(0.01)	(0.02)	(0.03)
Foreign Ownership	0.019	0.018	-0.007	0.098***
	(0.04)	(0.02)	(0.04)	(0.00)
Age: 5-14	0.005	-0.009	0.005	0.026
	(0.01)	(0.01)	(0.01)	(0.03)
Age: 15+	-0.044***	-0.041***	-0.019**	-0.054
	(0.01)	(0.01)	(0.01)	(0.03)
New Equipment	-0.058***	-0.022**	-0.065***	-0.019***
	(0.01)	(0.01)	(0.01)	(0.00)
Older Equipment	-0.097***	-0.014***	-0.122***	-0.030*
	(0.02)	(0.00)	(0.01)	(0.02)
Out-of-date Equipment	-0.139***	-0.101	-0.086***	-0.002
	(0.03)	(0.06)	(0.03)	(0.01)
ENV = Economic Environment				
Diversity	0.244	0.315	-0.192	-0.406***
	(0.43)	(0.20)	(0.28)	(0.05)
Specialization	-1.157***	-0.546***	-0.710***	-0.268
	(0.34)	(0.13)	(0.14)	(0.23)

Notes: Time-fixed effects and locational fixed effects *LOC* included.

***Significant at 1% level, **Significant at 5% level, *Significant at 10% level

Source: own calculation

Table B.5
Difference in parameter tests for city and innovation types (Model 2)

	Product Improvement	Product Introduction	Process improvement	Organizational Innovation
Chi-square difference in parameter tests if closest city is a metropolis				
Product Improvement	---	4896.79***	73.66***	256.59***, °°
Product Introduction	4896.79***	---	42.96***	90.15***, °°
Process improvement	73.66***	42.96***	---	22.59***, °°
Organizational Innovation	256.59***, °°	90.15***, °°	22.59***, °°	---
Chi-square difference in parameter tests if closest city is a large city				
Product Improvement	---	31.66***, °°	11.03***	7191.17***
Product Introduction	31.66***, °°	---	34.57***, °°	5.54*, °°
Process improvement	11.03***	34.57***, °°	---	14.74***
Organizational Innovation	7191.17***	5.54*, °°	14.74***	---
Chi-square difference in parameter tests if closest city is a small city				
Product Improvement	---	10.28***, °°	1.03	183.65***, °°
Product Introduction	10.28***, °°	---	12.69***, °°	1.19°°
Process improvement	1.03	12.69***, °°	---	1.17°°
Organizational Innovation	183.65***, °°	1.19°°	1.17°°	---

***Significant at 1% level, **Significant at 5% level, *Significant at 10% level

°° Joint significance test for distance decay variables are not significant

Source: own calculation

Table B.5
Difference in parameter tests for city and innovation types (Model 2)

	Product Improvement	Product Introduction	Process improvement	Organizational Innovation
Chi-square difference in parameter tests if closest city is a metropolis				
Product Improvement	---	4896.79***	73.66***	256.59***, °°
Product Introduction	4896.79***	---	42.96***	90.15***, °°
Process improvement	73.66***	42.96***	---	22.59***, °°
Organizational Innovation	256.59***, °°	90.15***, °°	22.59***, °°	---
Chi-square difference in parameter tests if closest city is a large city				
Product Improvement	---	31.66***, °°	11.03***	7191.17***
Product Introduction	31.66***, °°	---	34.57***, °°	5.54*, °°
Process improvement	11.03***	34.57***, °°	---	14.74***
Organizational Innovation	7191.17***	5.54*, °°	14.74***	---
Chi-square difference in parameter tests if closest city is a small city				
Product Improvement	---	10.28***, °°	1.03	183.65***, °°
Product Introduction	10.28***, °°	---	12.69***, °°	1.19°°
Process improvement	1.03	12.69***, °°	---	1.17°°
Organizational Innovation	183.65***, °°	1.19°°	1.17°°	---

***Significant at 1% level, **Significant at 5% level, *Significant at 10% level

°° Joint significance test for distance decay variables are not significant

Source: own calculation

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Imprint

IAB-Discussion Paper 22/2017
26 July 2017

Editorial address
Institute for Employment Research
of the Federal Employment Agency
Regensburger Straße 104
D-90478 Nuremberg

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Website
http://www.iab.de

Download of this Discussion Paper
http://doku.iab.de/discussionpapers/2017/dp2217.pdf

ISSN 2195-2663

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