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DETERMINANTS OF FOREIGN TECHNOLOGICAL ACTIVITY IN GERMAN REGIONS – A COUNT MODEL ANALYSIS OF TRANSNATIONAL PATENTS (1996-2009)

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DETERMINANTS OF FOREIGN TECHNOLOGICAL ACTIVITY IN GERMAN REGIONS – A COUNT MODEL ANALYSIS OF TRANSNATIONAL PATENTS (1996-2009)

This paper analyses the determinants of spatial distribution of foreign technological activity across 96 German regions (1996-2009). We identify foreign inventive activity by applying the 'cross-border-ownership concept' to transnational patent applications. The descriptive analysis shows that foreign technological activity more than doubled during the observation period with persistent spatial heterogeneity in Germany. Using a pooled count data model, we estimate the effect of various sources for externalities on the extent of foreign technological activity across regions. Our results show that foreign technological activity is attracted by technologically specialised sectors of regions. In contrast to existing findings this effect applies both to foreign as well as domestic sources of specialisation. We show that the relation between specialization and foreign technological activity is non-linear and that it is influenced by sectoral heterogeneity. Externalities related to technological diversification attract foreign R&D only into 'higher order' regions.

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1. Introduction

The analysis of the nature and strategic behaviour of the multinational enterprise (MNE) has been undertaken mainly by drawing upon transaction cost based international business theory (Buckley and Casson, 1976; Dunning 1977) as well as international trade theory (see Helpman 2006 for an overview). Both focus on the relationship between foreign direct investment (FDI), information and organisation. Very little work, however, has taken place in both fields concerning the sub-national regional location behaviour of the MNE (McCann and Mudambi 2005). Geography in this literature is defined simply in terms of home country versus foreign country.

The country level perspective dominates also in existing research on determinants of R&D internationalisation (see Hall 2011 for an overview). This literature suggests that access to foreign markets, R&D and human capital are main drivers of R&D internationalisation (ibid). Other relevant factors include to the quality of the intellectual property rights regime (Kumar, 1996; Ito and Wakasugi, 2007), R&D policy (Hines 1993, 1994; Bloom et al. 2002; Athukorala and Kohpaiboon 2010; Thompson 2013) as well as geographic and cultural proximity between home and host country (Castellani et al. 2011; Dachs and Pyka 2010).

In contrast the technological accumulation approach towards explaining the growth of international firms suggests that MNEs' location of technological activities depends upon the interrelationship between their corporate strategy and their sub-national location specific characteristics (Cantwell 1989, 1995; Cantwell and Piscitello 2005). Drawing from the literature on the spatial organisation of R&D (Malecki 1985; Howells 1990), as well as the geography of innovation (Feldman 1994; Audretsch and Feldman 1996; Carrincazeaux et al., 2001), it is assumed that geographic proximity, localised knowledge spillover and agglomeration related externalities are highly relevant for the location pattern of foreign R&D and innovation.

Related empirical research indicates that MNEs' networks for R&D and innovation in Europe conform to a geographical hierarchy of regional centres within and across countries (Cantwell and Immarino 1998, 2000, 2001, 2003; Cantwell, 2000; Cantwell and Noonan, 2002). The assumption is that regional agglomerations of knowledge and capabilities attract FDI in technological activities to a different extent and with a different sectoral spread, depending upon the position of the region in the geographical hierarchy (Cantwell and Immarino 1998, 2000).

Despite a recent surge in research on MNEs' sub-national location choice (see for example Guimarares et al., 2000; Crozet et al, 2004; Barrios et al, 2006; Basile et al, 2008;

Gauselmann and Marek, 2012; Marek, 2012), we find only few studies that investigate the location determinants of foreign R&D and innovation at a sub-national level of analysis. Notable exceptions (Verspagen and Schoenmakers, 2004; Cantwell and Piscitello 2005, 2007) to this identify technological specialisation, diversification, as well as science and education infrastructure as important sources of knowledge spillover within and across regions, which affect the localisation of technological activities of MNEs.

Existing research also demonstrates the complexity in disentangling competition and agglomeration related effects on location of foreign technological activities. Knowledge spillovers are not unidirectional as they may correspond to knowledge inflows or outflows (Mariotti et al., 2010). Whereas the former is generally assumed to be positive, the latter could be linked with unintentional knowledge leakage. Therefore, it is suggested that the effect of knowledge spillovers depends upon the competitive position of MNEs versus local competitors (McCann and Mudambi, 2004; McCann and Mudambi, 2005, Rosenthal and Strange, 2004; Alcacer and Chung, 2007; Mariotti et al, 2010).

Cantwell and Iammarino (2002) analyse US patents granted to the worlds' largest multinationals with research locations in the UK, France, Italy and Germany (1969-1995). They show that since the 1970s Germany attracted most technological activity by foreign firms in Europe, although the share of foreigners in equivalent aggregate patenting activity was relatively low. According to recent evidence from transnational patent applications, the share of Germany in absolute foreign technological activity in the EU27 continued to grow between 2001 and 2009, whereas the corresponding shares of the UK and France declined over the same period (IWH et al. 2013). Germany does not only attract most foreign R&D, it is also characterised by the highest cross-regional dispersion of patented research (Cantwell and Noonan, 2002). Despite its importance for foreign R&D Germany has received comparatively little attention from analysts of the MNE. This applies in particularly to the analysis of forces shaping the regional distribution of foreign technological activities.

This paper contributes to the existing research in various ways: (1) It provides evidence on the determinants of foreign technological activities at the sub-national level for Germany as the biggest single host of foreign R&D within the EU27. (2) We exploit a novel dataset that identifies foreign technological activity by transnational patent applications with at least one foreign applicant and at least one inventor located in one of the 96 German planning regions for the period 1996-2009. This is the first time that the 'cross-border-ownership' principle to measure R&D internationalisation is combined with regionalised patent information. (3) We test the effect of localised knowledge spillover on the level of foreign technological activity. We pay particular attention to the nature of technological specialisation and diversification. Thereby we differentiate foreign and domestic sources of specialisation and account for region and sector-specific influences.

The subsequent article is structured in the following way: Section 2 provides a conceptional background and motivates the research hypotheses of our investigation. Section 3 describes the dataset and provides some basic descriptive statistics. The following section introduces the adopted indices and econometric approach. Section 5 describes the estimation results. The final section provides a tentative conclusion from our research.

2. Conceptional background and hypotheses

Knowledge or technological externalities associated with specialisation externalities or localisation economies can be related back to Marshall (1962) as one aspect of the so-called agglomeration economies. Knowledge externalities accrue not only to competitors, suppliers and customers with regard to production activities within a specific location; they apply similarly to R&D and innovation. A specialised workforce of skilled engineers with experience in a certain field of research, and specialised firms that can supply certain types of instruments/services, can constitute important inputs into the R&D process (Saxenian 1994). Therefore an emerging spatial cluster of R&D activities may provide important advantages to the ‘members’ of such a cluster and thus a self-reinforcing process may set in that leads to strong spatial concentration (Verspagen and Scheonmakers 2004).

The second explanation for the spatial concentration is related to the nature of knowledge itself. While information is rather easy to codify, this is not the case for knowledge due to its tacit dimension (Cowan et al. 2000). According to Polyani (1967) creative acts and in particular acts of discovery depend crucially on personal feelings and commitment. Von Hippel (1994) argues that ‘sticky knowledge’ cannot be transferred at non-significant costs. Geographic distance hinders the exchange of tacit knowledge (Jaffe 1989; Jaffe et al. 1993; Feldman 1994; Audretsch and Feldman 1996; Jaffe and Trajtenberg 1996). Cantwell (1989, 1995) holds that technological knowledge is not perceived as an immediately usable intermediate input but rather as an input into the collective learning process of the firm by which tacit capability is generated. Therefore, MNEs need to be on site with their own production and innovatory capacity if they are to benefit from the latest advances in geographically localised technological developments to feed their innovation (Cantwell 1989; Kogut and Chang 1991).

Intra-industry or specialisation spillover

Taking both arguments – specialisation externalities and the tacit nature of knowledge – into consideration, Cantwell and Piscitello (2005) hypothesise that MNEs are more likely to locate their research activities in regions where other firms are technologically active within the same industry. Up to this point the theoretical arguments would support the hypothesis, that:

(H1) Technological specialisation in a given industrial sector of a region relative to other regions within a host country has a positive effect on foreign technological activity within this sector of the region.

Although, it has been established that in particular R&D intensive industries tend to be highly spatially concentrated (see for example Castells and Hall 1994, Saxenian 1994, Almeida and Kogut 1997), the participation of MNEs in such specialised agglomerations seems not unconditional. Cantwell and Piscitello (2005) analyse US patents granted to the world's largest industrial firms in the regions (NUTS-2 level) of Germany, France, the UK and Italy (1987-1995) and find evidence of positive intra-industry spillover on the co-location of foreign owned technological activity. However, they find the effect negative or insignificant on foreign technological activity, when it is due to the presence of other domestic owned firms.

Cantwell and Piscitello (2005) argue where technological specialisation is concentrated in a few domestic firms that raise entry barriers, any industry specific agglomeration effect may be offset by a competitive deterrence effects, both in terms of bidding for local resources and of the availability of potential local technological spillovers. An alternative explanation could be that technologically advanced MNEs try to avoid potential unintended knowledge leakage to domestic firms with a technological advantage in the same industry (McCann and Mudambi 2005, Mariotti et al. 2010). This sort of adverse selection might be particularly relevant for investments in technological activities by large foreign technological leaders in oligopolistic industries (Cantwell and Santangelo 1999, Chung and Alcacer 2007). At the same time, location specific domestic technological specialisation could attract entries by technologically lagging foreign firms (Chung and Alcacer 2007) or foreign firms from other industries following technological diversification strategies, which are not direct competitors of local leaders (Cantwell and Kosmopoulou 2002).

In contrast, the presence of other foreign-owned firms within the same region and sector does not only provide potential access to specialisation advantages, it also generates externalities with regard to location-specific information costs needed to investigate the local endowment of factors prior to first entry (Mariotti and Piscitello 1995; He 2002; Mariotti at al. 2010). These lines of argument suggest a refinement of our first research hypothesis in the following way:

(H1.1) Specialisation of foreign technological activity in a given industrial sector of a region relative to other regions within a host country has a positive effect on subsequent foreign technological activity within this sector of the region.

(H1.2) Specialisation of domestic technological activity in a given industrial sector of a region relative to other regions within a host country has a negative effect on subsequent foreign technological activity within this sector of the region.

Inter-industry or diversification spillover

A second source of spillover stems from the variety associated with the co-presence of firms from different industries and technological fields. The more diverse the technological activity within the region, the more firms could potentially benefit. Such spillover relate to diversity externalities which favour the creation of new ideas across sectors and which go back to the concept of 'urbanisation economies' (Jacobs, 1969). Innovative firms may benefit from technological developments in industries other than their own (Devereux et al., 2007). This may make diversified regions attractive locations for foreign R&D (Cantwell and Piscitello, 2005). Therefore, we can hypothesise:

(H2) A higher diversification across industries of a region compared to other regions within a host country has a positive effect on foreign technological activity within the region.

Building upon Christaller's (1966) central place theory the literature distinguishes between so called 'higher' and 'lower order regions' that arise as a consequence of the interaction and consequence of diversity and specialisation economies, which in turn are location specific. Cantwell and Iammarino (2001, 2003) argue that inter-industry spillover is more likely to occur in all-round 'higher order' regions, which facilitate greater opportunities for inter-company alliances for the purposes of technological collaboration and exchange. The technological activity of domestic and foreign firms in these regions is typically broad ranging in nature and extends across a spectrum of, often general purpose, technologies. Here it is possible that relationships are established between actors in otherwise quite separate alternative fields of specialisation (Cantwell and Piscitello 2000). Foreign firms that locate in 'higher order' regions establish their competitive advantage through, *inter alia*, their ability to tap into a variety of extant technologies (Cantwell and Noonan, 2002). In such regions the specialisation pattern of foreign firms is not expected to emulate that of indigenous firms (ibid). In contrast, localisation economies are suggested to lead to more focused foreign participation in the overall local research efforts in ‘lower order’ regions (Cantwell and Immarino 2001, Cantwell and Noonan, 2002). In such regions the composition of technological specialisation of foreign owned affiliates follows more closely the equivalent pattern of specialisation of domestic firms (Cantwell and Immarino 1998, 2000, 2001). Therefore, we can further hypothesize:

(H2.1) In ‘higher order regions’ within a host country diversity spillover have a stronger effect on subsequent foreign technological activity compared to specialisation spillover, which dominate in ‘lower order regions’.

Science-Industry-spillover

The efforts of firms to advance technology do not proceed in isolation, but are strongly supported by public research centres, universities, industry associations, an adequate education system and an excellent science base (Kline and Rosenberg 1986; Nelson 1993; Rosenberg and Nelson 1996; Nelson and Rosenberg 1999; Breschi 2000). There is growing evidence that such science-technology spillover tends to be spatially bounded (Jaffe et al. 1993; Audretsch and Feldman 1996; Audretsch and Stephan 1996; Acs et al. 2000; Adams 2001). This could be especially true for foreign-owned firms, which tend to have a greater degree of mobility when locating their corporate research, and so pay, for example, greater attention to being close to relevant public research facilities (Görg and Strobl 2003). Cantwell and Piscitello (2005) find R&D employment in the public sector and the educational base within regions, as well as in adjacent regions, to constitute significant pull factors for foreign owned R&D. Therefore, we hypothesize:

(H3) The potential for science-industry spillover within a region of a host country has a positive effect on foreign technological activity within the region.

3. Data and descriptive statistics

The first best choice would be a dataset on foreign technological activities that provides information on the location where technological activities of foreign firms take place at a sub-national level and provide information about the ownership of the generated technological knowledge. As such detailed R&D statistics are not available, so far only few patent based datasets[5] have been able to account for ownership structures and international sub-national geographic distribution of technological activities in multinational firms. Given

[5] University of Reading Database (USPTO data 1969-1995: see for example Cantwell and Piscitello 2000; Cantwell and Noonan 2002; Cantwell and Piscitello 2002, 2005; Cantwell and Santangelo 2002; Santangelo 2002; Criscuelo et al. 2005; Narula and Santangelo 2009); SPRU Database (USPTO 1960-1996: see for example Patel and Vega 1999, Le Bas and Sierra 2002, 2005; EPO data 1991-2006: Patel 2010) and INSEAD Database (USPTO data 1975-1995: see for example Singh 2008, Alnuaimi et al 2012).

the complex matching-procedures involved when linking patent and firm ownership data, resulting datasets are often restricted to a limited number of large multinational firms or to a specific industry or technological area. In addition, it seems that corresponding datasets do not cover the most recent period of globalisation (1995-2010), which witnessed a considerable surge in R&D internationalisation (OECD 2008a, 2008b).

Given the above outlined constraints, we use an approach to identify foreign technological activity at a sub-national level in Germany which has frequently been used in the literature. We apply the 'cross-border-ownership' approach (Guellec und van Pottelsberghe de la Potterie 2001; OECD 2009) that assumes a case of R&D internationalization if at least one inventor of a given patent application resides in a different country from the applicant of the respective patent application. In most cases, patents with applicants from abroad and a domestic inventor correspond to inventions made at the research laboratories of multinational companies and applied for at company headquarters (Guellec und van Pottelsberghe de la Potterie, 2004; OECD, 2009). In this context, foreign control means that the economic benefits arising from the inventions are shared among countries: the country of invention (in our case Germany), the country of ownership (in our case a foreign country), but also partly other countries, as multinational companies may implement part of their technology worldwide (OECD, 2009). However, the 'cross-border-ownership' concept can lead to an underestimation of foreign R&D for two reasons: a) the patent can be owned (or applied for) directly by a domestic subsidiary of a multinational group, which therefore is not mentioned as such in the patent file; and b) a patented invention can be controlled by a foreign entity *ex post*, after its initial owner was acquired by or merged with this foreign entity or the patent right was transferred to the foreign entity (Cincera, et al. 2006; OECD, 2009).

The 'cross-border-ownership' approach has already been applied by in recent country level studies of R&D internationalization (see for example Guellec und van Pottelsberghe de la Potterie, 2004; Erken und Kleijn 2010; Dachs und Pyka 2011). To our best knowledge this is the first application to a sub-national level of analysis of foreign technological activity. We use Patent Cooperation Treaty (PCT) applications as well as applications to the European Patent Office (EPO) with at least one applicant located in a foreign country and at least one inventor located in one of the 96 German functional planning regions (RORs)[6] with a priority year between 1996 and 2009. We use all PCT applications and EPO applications, which have not been transferred into the European phase of a PCT application, which avoids double counting (Frietsch et al. 2010). This way we identify patent

[6] *'Raumordnungsregionen'* are functional regional units based on commuting data and more suitable for spatial analysis of economic activity compared to purely administrative regional units. Their size is between NUTS2 and NUTS3.

families with at least one PCT or EPO application. The data is drawn from the OECD REGPAT Database (Edition Januar 2012), which is derived from the Worldwide Statistical Patent Database (PATSTAT) and facilitates a differentiation according to technological areas as well as regionalization of the patent data. The allocation to 35 technological areas follows the WIPO IPC-Technology Concordance, which in turn can be transformed by using a concordance matrix into 22 manufacturing industries (NACE Rev 1.1, 2-digit-level) (see Schmoch et al., 2003; Schmoch, 2008). By disaggregating patent applications by industry, it is possible to link our dependent variable to selected industry-specific explanatory variables. This way we can test for a relation between economic activities within regions and their technological performance.

Descriptive analysis

The total number of patent applications with at least one Foreign Applicant and at least one German Inventor (FAGI) more than doubled during the observation period (1996-2009) (see Table 1).

Table 1: Patent applications with at least one foreign applicant and at least one German inventor (FAGI) across German regions (1996 to 2009)

Priority Year	FAGI total	FAGI min.	FAGI max	FAGI mean	Variation coefficient
1996	2089.23	0.00	178.26	21.76	1.66
1997	2318.48	0.00	206.07	24.15	1.72
1998	2946.92	0.00	295.97	30.70	1.77
1999	3223.74	0.00	256.06	33.58	1.67
2000	3603.69	0.50	261.52	37.54	1.54
2001	3732.02	0.00	327.78	38.88	1.61
2002	4007.80	0.00	415.34	41.75	1.63
2003	4398.04	0.33	523.40	45.81	1.73
2004	4469.72	0.00	467.37	46.56	1.58
2005	4876.88	0.00	434.57	50.80	1.62
2006	4736.27	0.00	398.48	49.34	1.54
2007	5044.30	0.00	503.34	52.54	1.56
2008	4682.97	0.00	456.08	48.78	1.58
2009	4381.47	0.00	410.46	45.64	1.47

Source: OECD REGPAT (Edition January 2012). Own calculations.

Over time not only the total number and mean increase but also does the range between minimum and maximum values across all regional units (RORs) in Germany. Jointly with the large, nearly stable variation coefficient, this points to a persistent heterogeneity of foreign technological activity across the 96 German regions. This is supported if we take a look at the distribution of the number of FAGI across the regions (RORs) in the year 2009 (see figure 1).

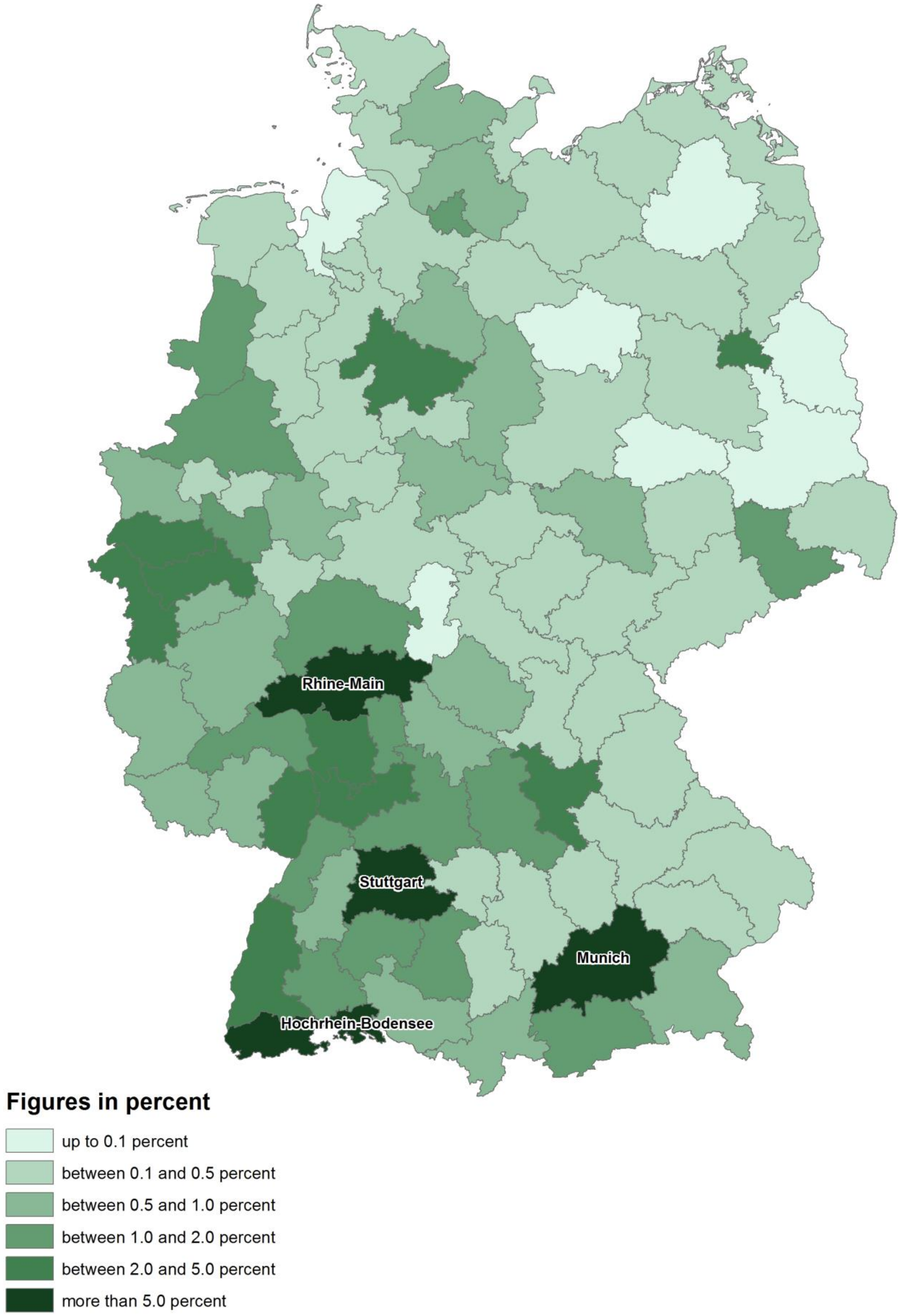
In the observation period foreign technological activity concentrates in the southern and south-western part of Germany, in particular in the regions Munich, Stuttgart, Rhine-

Main, and Hochrhein-Bodensee. Each of these regions hosts more than 5 per cent of the total foreign patenting activity in Germany (FAGI). Another eight regions in different geographic directions (Duesseldorf, Industrieregion Mittelfranken, Unterer Neckar, Cologne, Berlin, Suedlicher Oberrhein, Starkenburg, and Hamburg) account for shares between 2 and 5 per cent, another 12 regions have each a share between 1 and 2 per cent. The remaining 71 regions account each less than 1 per cent of total foreign technological activity.

The top ten region measured by absolute number of total patent applications during the observation period, tend also to rank high in terms of attracting foreign patenting activities. Foreign shares in total patenting activities between 1995 and 2009 range between 5 and 57 per cent. However, the top ten regions by that measure include both, regions characterised by very high levels of total technological activity as well as regions with low levels of technological activities. The highest growth rates (5 to 32 per cent) of foreign technological activities (1995-2009) can be observed in a group of about 20 regions with fairly low starting levels. This group includes almost half of all regions from East Germany.

In general, foreign technological activity is spatially dispersed with a persistent pattern over time. Northern German as well as eastern German regions – with exceptions of Hamburg, Berlin, and Hannover – account for comparatively little foreign technological activity. Most of it is concentrated in southern and south-western regions. However, the spatial pattern seems to reject a simple East-West division.

Figure 1: *FAGI patent applications per planning region (ROR) in Germany in % of total FAGI patent applications, 2009*



Note: FAGI = patent with at least one foreign applicant and at least one German inventor; ROR = planning region (Raumordnungsregion).

4. Econometric model and specification of the variables

4.1 Indices adopted

To capture the effect of specialization externalities, we use the revealed technological advantage index (RTA), a concept first developed for the country level (Soete 1987) and later adapted for company patterns (Cantwell 1989, Patel and Pavitt 1991). It measures a relative technological specialisation of a region in a given sector in relation to all other regions within the host country. Thereby, it controls for the propensity to patent in a particular sector as well as the size of the region analysed. The RTA index is calculated on the basis of the number of patent applications for each year (1995 to 2008). We distinguish two RTA indices, to differentiate for specialisation of foreign technological activities within the region *(Foreign Technological Specialization)* and technological specialisation of domestic firms *(Domestic Technological Specialisation)*. The index *RTA* can be written as follows:

$$RTA_{ijt} = \frac{P_{ijt} / \sum_i P_{ijt}}{\sum_j P_{ijt} / \sum_{ij} P_{ijt}}.$$

P denotes the number of patent applications of at least one foreign applicant and at least one German inventor in case of foreign specialization and the number of patent applications with at least one German inventor but only German applicants in case of domestic specialisation, respectively. Both groups of patent applications are mutually exclusive and the sum of both corresponds to total patent applications within the respective region and year. Therefore, we are also able to calculate an RTA index based on all patent application, which reflects the overall technological specialisation of the region. The indices denote the sector (*i*), region (*j*) and year (*t*). Values of $RTA>1$ suggest that a region is comparatively specialized (advantaged) in sector i, whereas $RTA<1$ points to a comparative disadvantage (non-specialization).

Following Basile et al. (2012) we measure externalities related to inter-industry or diversification spillover within a region by using the median location quotient (MLQ):

$$\tilde{S}_{it} = \frac{S_{it,J/2} + S_{it,J/2+1}}{2} \quad with \quad S_{ijt} = \frac{P_{ijt} / \sum_j P_{ijt}}{\sum_i P_{ijt} / \sum_{ij} P_{ijt}},$$

where $\tilde{S}$ is the median of location quotient *S*. The location quotient is calculated on the basis of the number of patent applications *P* in sector *i* and region *j* in year *t*. The median

S_{ijt} is a measure of the number of sectors in which a region shows a revealed comparative advantage: A high median indicates that a region has a comparative advantage in a large number of sectors, and therefore it is diversified, whereas a low median means that a region is not diversified.

It is important to note that specialization (RTA) and diversification (MLQ) follow different theoretical and measuring concepts. The RTA index relies on Marshall's theoretical consideration of externalities stemming from specialization (intra-industry spillovers). Thus, the RTA index as calculated here is specific to a region and industry. Multiple specialization within one region is of course possible. Multiple specialization does, however, not mean diversification. The MLQ index follows Jacob's theoretical concept of externalities deriving from diversification (inter-industry spillovers). Thus, MLQ is measured on the region level solely.

4.2 Econometric model and specifications

Our dependent variable is defined as the number of patent applications with at least one foreign applicant and at least one German inventor (FAGI) for each of the 22 manufacturing sectors (NACE 2 digit level) in each of the 96 planning regions (RORs) for the years 1996 to 2009 (14 years period) in Germany. This corresponds to a total of 29,568 cases (22*96*14). The frequency distribution of the dependent variable (FAGI) is extremely skewed to the left and thus, suggests the use of a count data model.

Since a patent application can be allocated to different international patent classes (IPC) and a patent application can have German inventors in more than one region, we use fractional counting i.e. patent applications are allocated proportionally across industries and regions. This results in fractional counts of FAGI. However, a count data model assumes integer counts. In order to fulfil this assumption, we round up the fractional counts of FAGI to the next integer. All values of FAGI above 0 and below 1 are rounded to 1. This transformation increases the mean of the dependent variable (see Annex Table A1), which may result in a slight overestimation of the effect of the explanatory variables. To take this into account, we need to restrict the interpretation of estimation results to the sign and the size of the coefficients instead of the coefficients itself.

Since the variance (43.42) of the transformed dependent variable substantially exceeds its mean (2.54) (see Annex Table A1), our econometric approach needs to account for overdispersion. Therefore, we apply a negative binomial regression model instead of the standard Poisson model. This model is an 'extended' Poisson model that allows for individual unobserved effects and thus captures the source of overdispersion (Winkelmann and Boes, 2006). A Voung test of excess zeros shows that no zero inflation of this model is necessary.

The resulting pooled binomial regression model can be described as follows:

$$FAGI_{ijt} = \exp\left(X_{ijt-1}\beta + \varepsilon_{ij}\right).$$

FAGI is the number of patent applications with at least one applicant located in a foreign country and at least one inventor located in Germany in region *i* and sector *j* over the time period 1996 to 2009, where *i=1,…,96* regions and *j=,15,…,36* denotes the NACE code of the 22 manufacturing sectors.

Vector *X* contains in our specification *(1)* the following key explanatory variables: the overall technological specialisation of the region *i* and sector *j* measured by the RTA index based on all patent applications in the region (for a detailed overview of variable measurement see Annex Table A3); the technological diversification of region *i* measured by the median of location quotient; and the number of students per inhabitants of region *i* as proxy for science and education infrastructure. These three variables proxy the main sources of knowledge spillovers in line with our hypotheses (1) to (3). In addition, we introduce a dummy variable between the overall technological specialisation and high-tech industries[7]. The underlying rationale is that the relevance of externalities related to technological specialisation varies depending upon the R&D intensity of the sector in question (Castells and Hall, 1994; Saxenian, 1994; Almeida and Kogut, 1997). We also introduce the number of prior patenting activity in the region *i* and sector *j* to control for a dynamic interaction between corporate strategy and location specific technological characteristics as well as cumulative causation (Cantwell 1989, 1995, Cantwell and Piscitello 2005). The specification is completed by a set of selected variables commonly used in industrial location choice literature, which can be assumed to affect the profit function of firms: the share of high qualified employees in the total number of employees of the region *i* and sector *j* as proxy for sector specific human capital availability; the business tax rate of the region *i* as a proxy for region specific location costs, quality of transport infrastructure of the region *i;* an index of the quality of health system of the region *i*, the size of the region *i*; and a dummy for regions that host the capital of the corresponding federal state. The inclusion of this particular set of variables seems adequate in order not to restrict the specification to technology based explanatory variables, which could lead to a potential omission variable bias of estimation

[7] Based on the OECD classification high-tech sectors correspond to: NACE codes 24, 29, 31, 33, 34 and 35 (see Hatzichronoglou, 1997).

results. Finally, we include as dummies for sector, year and federal state. The error term ε captures individual unobserved heterogeneity.

In *specification (2)* we differentiate overall technological specialisation into foreign technological specialisation and domestic technological specialisation. Following, Cantwell and Piscitello (2005) we measure both on the basis of a RTA index. However, the key argument underlying our hypotheses *(1.1)* and *(1.2)* relates to the 'dominant position' of domestic firms within a particular sector, which could create entry barriers and crowding out for new foreign entries. It seems that differentiating the RTA index for foreign and domestic patent application does not fully capture this aspect, since the basis of both varies. Alternatively, in specification *(3)* we introduce in addition to foreign/domestic technological specialisation another varibale that measures a dominant domestic technological position. The varible measures the difference between domestic and foreign cumulative patent applications within the respective region *i* and sector *j*. A positive value is assumed to indicate a dominant technological position of domestic firms.

Specfication (4) to (6) address hypothesis 2.1, which scrutinises test whether technological specialisation and diversification externalities differ in their effect on foreign technological activity depending upon the position of the respective region. In line with existing approaches (see for example Cantwell and Iammarino 2001) we differentiate 'higher-order' and 'lower-order' regions by their share of patenting activities within a host country. We assume that a region which has a total number of patent applications across all sectors during the observation period above the mean of all German regions can be regarded as 'higher-order' regions. We subsequently calculate interaction terms between a dummy 'higher-order' regions and the relevant explanatory variables: foreign technological specialisation region *i* and sector *j*, domestic technological specialisation region *i* and sector *j*, *and* technological diversification of region *i.* In order to mitigate multi-colinearity we need to test for the effect of each these interaction terms in spate specifications.

Using functional instead of purely administrative regional units of analysis mitigates the problem of potential spatial correlation (Eckey et al, 2006). However, the problem might still occur. In fact, the figure 1 above indicated the existence of regional clusters of foreign technological activity – or potential spatial correlations between neighbouring regional units (RORs). The results of the Morans I tests on the basis of the standardized neighbourhood matrix also point to the existence of spatial correlations between neighbouring regions (see Annex Table A2). To overcome this problem, we use spatial lags of our key explanatory variables in all above specifications.

Finally we also need to address the problem of potential endogeneity of our dependent variable and explanatory variables, since the economic and technological activity of foreign firms may affect the region and sector specific endowment factors. Therefore, all explanatory variables enter the model with a one-year-lag. In order to check the robustness of the estimation results we re-estimate the specifications using an alternative five-year-lag structure.

5. Estimation results

The results of specification (1) indicate that a revealed technological advantage of a region in particular economic sector in comparison to other regions in Germany has a positive effect on the extent foreign technological activity within the region i.e. the number of patent applications with at least one foreign applicant and at least one Germany innovator (FAGI) (see Table 2 below). This result is in line with our first research hypothesis that specialisation of technological activity in a given industrial sector of a region relative to other regions within a host country has a positive effect on subsequent foreign technological activity with this sector of the region.

In specification (2) we differentiate between domestic and foreign sources of technological specialisation within the region. The results indicate that both foreign and domestic specialisation within the region have a positive effect on the extent of foreign technological activity. Based on this result we cannot reject hypothesis 1.1 that specialisation of foreign technological activity in a given industrial sector of a region relative to other regions within a host country has a positive effect on subsequent foreign technological activity with this sector of the region. Although, the positive effect of domestic technological specialisation is considerably smaller compared to foreign technological specialisation, we need to reject hypothesis (1.2) that postulated a negative relation between domestic technological specialisation of a region and its foreign technological activity within the same sector of activity.

The latter result is in principle also confirmed by the results of our third specification, which uses an alternative measure to approximate a ‘dominant technological position’ of domestic firms within the same sector and region. We find that in case the cumulative sum of prior domestic technological activity exceeds prior foreign technological activity, this has a positive, although very small, effect on subsequent foreign technological activity within the region. Thus, again our evidence does not support hypothesis (1.2).

It should be noted that the descriptive evidence suggests that the effect of technological specialisation (both foreign and domestic) is not linear (see Annex Figure A1). One possible source of non-linearity is sectorial heterogeneity. The descriptive evidence points to a much higher positive responsiveness of foreign technological activity to technological specialisation (both foreign and domestic) in high-tech sectors compared to low tech sectors, although the effect levels off and starts to fall beyond at a particular level of specialisation (see Annex Figure A2). Estimation results of specification (1) to (3) show a positive and significant coefficient for an interaction term between technological specialisation and high-tech sector, which suggests that the effect of technological specialisation is stronger in industries with high R&D intensity.

The estimation results of specification (1) to (3) indicate that a large number of sectors with a comparative technological advantage within a region has a significantly negative effect on foreign technological activity within the region (see Table 2). This evidence is in contrast to our research hypothesis (2) postulating that a higher diversification across industries of a region compared to other regions within a host country has a positive effect on subsequent foreign technological activity within the region.

Table 2 Estimation results – Specification (1) to (3)

Dependent variable: Foreign technological activity (FAGI)

Specification	(1)	(2)	(3)
Key explanatory variables			
Specialization (RTA)	0.3716***	-	-
	(0.0087)		
Foreign specialization (RTA foreign)	-	0.5819***	0.6067***
		(0.0090)	(0.0090)
Domestic specialization (RTA dom)	-	0.1000***	0.1105***
		(0.0067)	(0.0068)
Dominant domestic position	-	-	0.0001***
			(0.0000)
Diversification (MLQ)	-1.5079***	-1.6261***	-1.6907***
	(0.0331)	(0.0316)	(0.0316)
Science & education infrastructure (SEI)	0.0015***	0.0012**	0.0008
	(0.0005)	(0.0005)	(0.0005)
Control variables			
High Tech*RTA	0.1718***	-0.0136	0.0975***
	(0.0214)	(0.0196)	(0.0194)
Cumulative causation	0.0004***	0.0003***	-
	(0.0000)	(0.0000)	
Human capital endowment (HCE)	0.8906***	0.6922***	0.9631***
	(0.0725)	(0.0692)	(0.0681)
Business tax	-0.0011***	-0.0016***	-0.0019***
	(0.0004)	(0.0003)	(0.0003)
Transport infrastructure	-0.0230***	-0.0243***	-0.0267***
	(0.0011)	(0.0011)	(0.0011)
Health care index	0.1307***	0.1711***	0.1944***
	(0.0291)	(0.0277)	(0.0278)
Size of region	0.1327***	0.1248***	0.1331***
	(0.0149)	(0.0142)	(0.0143)
Capital city	0.2976***	0.3331***	0.4160***
	(0.0157)	(0.0148)	(0.0148)
Spatial lags			
Diversification neighbouring region	-0.4980***	-0.6153***	-0.5928***
	(0.0622)	(0.0594)	(0.0599)
HCE neighbouring region	-0.1664	-0.3247**	-0.3520**
	(0.1647)	(0.1570)	(0.1577)
SEI neighbouring region	0.0032**	0.0008	0.0017
	(0.0014)	(0.0013)	(0.0013)
Constant	0.9363***	1.1876***	1.0808***
	(0.2315)	(0.2211)	(0.2229)
Ln (alpha)	-2.1890***	-2.6767***	-2.6183***
	(0.0235)	(0.0312)	(0.0307)
Observations	29,269	29,269	29,269
Loglikelihood	-43,716	-42,328	-42,734
Chi-square	35,919	38,695	37,883
P-value Chi	0.0000	0.0000	0.0000
PseudoR2	0.291	0.314	0.307

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1
Coefficients for sector, federal state and year dummies are omitted in presentation.

Table 3 Estimation results – Specification (4) to (6)

Dependent variable: Foreign technological activity (FAGI)

Specification	(4)	(5)	(6)
Key explanatory variables			
Foreign specialization (RTA foreign)	0.5210***	0.6201***	0.6250***
	(0.0105)	(0.0085)	(0.0085)
Domestic specialization (RTA dom)	0.1288***	0.1005***	0.1171***
	(0.0065)	(0.0069)	(0.0065)
Dominant domestic position	0.0001***	0.0001***	0.0002***
	(0.0000)	(0.0000)	(0.0000)
Diversification (MLQ)	-1.4151***	-1.5616***	-1.5849***
	(0.0359)	(0.0365)	(0.0367)
Science & education infrastructure (SEI)	0.0014***	0.0011**	0.0011**
	(0.0005)	(0.0005)	(0.0005)
Interaction terms higher order region			
HOR*RTA foreign	0.2098***	-	-
	(0.0126)		
HOR*RTA domestic	-	0.1176***	-
		(0.0142)	
HOR*Diversification	-	-	0.1456***
			(0.0209)
Control variables			
Human capital endowment (HCE)	0.9548***	0.9765***	0.9943***
	(0.0680)	(0.0680)	(0.0681)
Business tax	-0.0027***	-0.0023***	-0.0024***
	(0.0003)	(0.0003)	(0.0003)
Transport infrastructure	-0.0273***	-0.0271***	-0.0274***
	(0.0011)	(0.0011)	(0.0011)
Health care index	0.2121***	0.2016***	0.2061***
	(0.0278)	(0.0279)	(0.0279)
Size of region	0.0834***	0.1087***	0.1006***
	(0.0145)	(0.0145)	(0.0149)
Capital city	0.4347***	0.4293***	0.4241***
	(0.0148)	(0.0149)	(0.0149)
Spatial lags			
Diversification neighbouring region	-0.5317***	-0.5564***	-0.5401***
	(0.0600)	(0.0601)	(0.0604)
HCE neighbouring region	-0.4168***	-0.3985**	-0.4129***
	(0.1576)	(0.1580)	(0.1582)
SEI neighbouring region	0.0059***	0.0039***	0.0044***
	(0.0014)	(0.0014)	(0.0014)
Constant	1.2090***	1.1073***	1.1719***
	(0.2223)	(0.2229)	(0.2230)
Ln(alpha)	-2.6359***	-2.6077***	-2.6101***
	(0.0307)	(0.0303)	(0.0304)
Observations	29,269	29,269	29,269
Loglikelihood	-42,607	-42,712	-42,722
Chi-square	38,137	37,927	37,907
P-value Chi	0.0000	0.0000	0.0000
PseudoR2	0.309	0.307	0.307

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1
Coefficients for sector, federal state and year dummies are omitted in presentation.

Estimation results of specification (1) and (2) indicate that a higher density of students in higher education institutions increases the extent of foreign technological activity within the region. This would support our research hypothesis (3) holding that the potential for science-industry spillover within a region of a host country has a positive effect on foreign technological activity within the region.

The existing literature argues that the role of localisation and diversification externalities for the location of foreign R&D differs depending upon the position within the hierarchy of regions. Our second set of estimations (see Table 3 above) is intended to reflect this argument. Estimation results of specifications (4) and (5) show that a revealed technological advantage has a higher additional positive impact on the extent of foreign technological activities in higher order regions. This applies again both to foreign technological specialisation and domestic technological specialisation, although the latter is again considerably smaller. The results of specification (6) show that a higher number of sectors with a comparative technological advantage within a region also has a negative effect on foreign technological activity within higher order regions. Although, the effect is less negative compared to the effect of diversification in lower order regions. Therefore, the estimation results of specification (4) to (6) suggest that we cannot support our research hypothesis 2.1 arguing that in higher order regions within a host country diversity spillover have a stronger effect on subsequent foreign technological activity compared to specialisation spillover, which dominate in 'lower order regions'.

Across specification (1) to (6) we find that all control variables are significant and have the expected sign (see Table 2 and 3 above): we find relative strong positive effect of industry specific human capital as well as for regions that host a capital of a federal state. The latter seems to indicate the relevance of urbanisation externalities apart from technological diversification. In addition, we find a negative effect of the level of local business tax and a positive effect on foreign technological activity in regions characterised by comparatively better transport[8] and health infrastructure.

Finally our estimation results indicate that spatial correlation exists, since we find significant inter-regional effects[9]. We find across all specification a significant negative effect of technological diversification of neighbouring regions on the extent of foreign technological activity within the region. In addition, we find positive inter-regional science and education infrastructure spillover when neighbouring regions are characterised by a relatively high

[8] The negative sign of the coefficient ‚auto' indicates that a longer journey time to reach the next highway from the region has a negative impact on the extent of foreign technological activity.

[9] We exclude the spatial lags of foreign and domestic specialization as they are highly correlated with other relevant variables, and are insignificant. The same applies to the spatial lag of overall specialization (see Annex Table A3).

density of students in higher education (apart from specification (2) and (3) in which the effect is insignificant). In addition, we find a negative effect of industry specific human capital in neighbouring regions on foreign technological activity within the region.

6. Conclusions

Most of the existing research on R&D internationalisation focuses on the comparative analysis of location factors at the national level of analysis. However, another stream of research points towards the relevance of agglomeration forces and the existence of a hierarchy of regions between and within host economies in the location of foreign R&D (see for example: Cantwell and Immarino 1998, 2000, 2001, 2003; Cantwell, 2000; Cantwell and Noonan, 2002; Chung and Alcacer, 2007; Verspagen and Schoenmakers, 2004; Cantwell and Piscitello 2005). This article puts the central arguments of this literature to a test. We do so at the example of Germany, which attracts most foreign R&D within the EU27 and shows a particularly pronounced pattern of spatial dispersion in comparison to other technologically leading European economies.

Our evidence supports the central tenet of existing research that a revealed technological advantage of regions is a crucial factor for attracting foreign R&D in that particular industry or technology. However, prior research emphasised that the direction of the specialisation effect depends on the expected on the dominant position of domestic firms (Cantwell and Piscitello, 2005, 2007) or else the balance of knowledge inflows and potential knowledge leakage to domestic firms (McCann and Mudambi, 2005, Mariotti et al., 2010) in the relevant sector. Whereas existing empirical investigations document negative or not significant effects of domestic technological specialisation on foreign technological activity (Cantwell and Piscitello, 2005), we find a positive effect, although considerably smaller in size compared to the corresponding effect of foreign specialisation within the region.

The obtained results could suggest that positive knowledge inflows outweigh the potential threat of knowledge leakage for most foreign firms investing in R&D in German regions. This could partially be explained to entries by technologically lagging foreign firms (Chung and Alcacer, 2007) or foreign firms from other industries following technological diversification strategies, which are not direct competitors of local leaders (Cantwell and Kosmopoulou, 2002). However, an alternative explanation could relate to our descriptive evidence on the non-linearity of specialisation effects. This in principle suggests that increasing returns to regional specialisation level off or even fall once a certain turning point has been reached. Thus sectors of regions with the highest revealed technological advantage deter foreign entry.

Our results also indicate that technological diversification has a negative effect on foreign R&D within regions ‘higher order regions’. Although, the effect is lower compared to ‘lower order regions, our finding is in contrast with prior research (Cantwell and Immarino 1998, 2000, 2001; Cantwell and Immarino 2001, Cantwell and Noonan, 2002). We also cannot confirm that localisation economies lead to more focused foreign participation in the overall local research efforts in ‘lower order’ regions (Cantwell and Immarino 1998, 2000, 2001Cantwell and Immarino 2001, Cantwell and Noonan, 2002). Our evidence seems to suggest even stronger effects of domestic specialisation in ‘higher order regions’.

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Appendix

Table A1: descriptive statistics of the original and the transformed dependent variable (FAGI); pooled for the observation period 1996-2009

	Original FAGI (fractional counts)	FAGI transformed (integers)
No. of cases	29,568	29,568
Minimum	0	0
Maximum	215.55	216
Mean	1.84	2.54
Variance	44.02	43.42
Skewness	11.44	11.60

Table A2: Results of the Morans I test for spatial correlations of FAGI in neighbouring regions; test based on the standardized neighbourhood matrix

Year	Morans I	E(I)	z-statistics	p-value
1996	0.001	-0.000	0.558	0.288
1997	0.000	-0.000	0.177	0.430
1998	0.001	-0.000	0.356	0.361
1999	0.002	-0.000	1.048	0.147
2000	0.001	-0.000	0.507	0.306
2001	-0.000	-0.000	0.091	0.464
2002	0.001	-0.000	0.678	0.249
2003	0.002	-0.000	0.801	0.211
2004	0.001	-0.000	0.482	0.315
2005	0.002	-0.000	0.816	0.207
2006	0.003	-0.000	1.121	0.131
2007	0.001	-0.000	0.681	0.248
2008	0.002	-0.000	0.958	0.169
2009	0.002	-0.000	0.932	0.176

Notes: Due to capacity restrictions of STATA, the test cannot be applied for the pooled data, and is therefore executed for yearly data.
Test results on the basis of the weighting matrix based on Euclidian distances between the regional capitals are very similar, and therefore are omitted.

Table A3: Variables used in the binomial regression model

Variable	Measurement	Source
Dependent variable		
Foreign technological activity (FAGI)	Number of patent applications with at least one foreign applicant and at least one German inventor per region (*Raumordnungsregion*) and sector (NACE Rev. 1.1, 2-digit level) and year	OECD RegPat database; own calculations
Key explanatory variables		
Specialisation (RTA)	Revealed technological advantage (RTA) Index of region, sector and year (basis: all patent applications with at least one German inventor)	OECD RegPat database; own calculations
Foreign specialisation (RTA)	Revealed technological advantage (RTA) Index of region, sector and year (basis: patent applications with at least one foreign applicant and at least one German inventor - FAGI)	OECD RegPat database; own calculations
Domestic specialisation (RTA)	Revealed technological advantage (RTA) Index of region, sector and year (basis: patent applications with only German applicant(s) and at least one German inventor - GAGI)	OECD RegPat database; own calculations
Diversification (MLQ)	Median location quotient (basis: all patent applications with at least one German inventor)	OECD RegPat database; own calculations
Dominant domestic position	Difference between cumulative GAGI and cumulative FAGI of region and sector and year	OECD RegPat database; own calculations
HOR (Higher Order Region)*RTA/MLQ	Interaction term of HOR and RTA or MLQ respectively; HOR (0/1) takes value of 1 if the number of all patent applications (with at least one German inventor) > mean of patent applivations over all 96 regions	OECD RegPat database; own calculations
Science & education infrastructure (SEI)	Number of students in higher education per 1,000 inhabitants of the region	INKAR database
Control Variables		
Cumulative causation	Cumulative number of all patent applications (with at least one German inventor)	OECD RegPat database; own calculations
Human capital endowment (HCE)	Share of highly qualified employees in the total number of employees with sector specific qualification in the region	INKAR database
Business tax	Business tax rate of the region	INKAR database
Transport infrastructure	Journey time to the next motorway by car	INKAR database
Healthcare index	Number of doctors and hospital beds related to the number of inhabitants region	INKAR database
Size	Log size of region in square kilometres	INKAR database
Capital	Dummy for the capital (federal state) in the region	own calculations
SEI neighbour	Average SEI of neighbouring regions	INKAR database
HCE neighbour	Average HCE of neighbouring regions	INKAR database
Diversification neighbour	Average MLQ (basis: all patent applications) of neighbouring regions	INKAR database
High Tech*RTA index	Interaction term of technological specialization and	OECD RegPat

	high-tech/medium-high tech sector	database; own calculations
Sector	Dummies for NACE Rev. 1.1 2 digit level NACE 15-35 (NACE 36 as reference)	own calculations
Federal states	Dummies for 16 Federal State (reference: Mecklenburg-Vorpommern)	own calculations
Year	Annual dummies 1997 – 2009 (reference: 1996)	own calculations

Note: All variables are available yearly; dependent variable: 1996-2009; explanatory variables 1995-2008.

Figure A1: Nonlinear effect of specialization on the number of patent applications of at least one foreign applicant and at least one National Inventor (FANI)

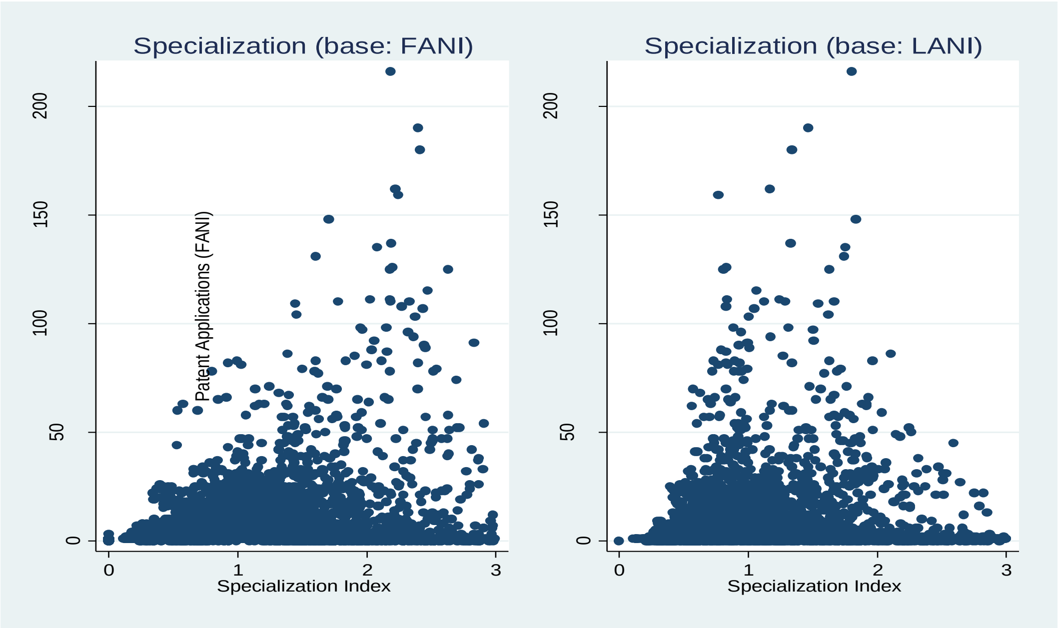
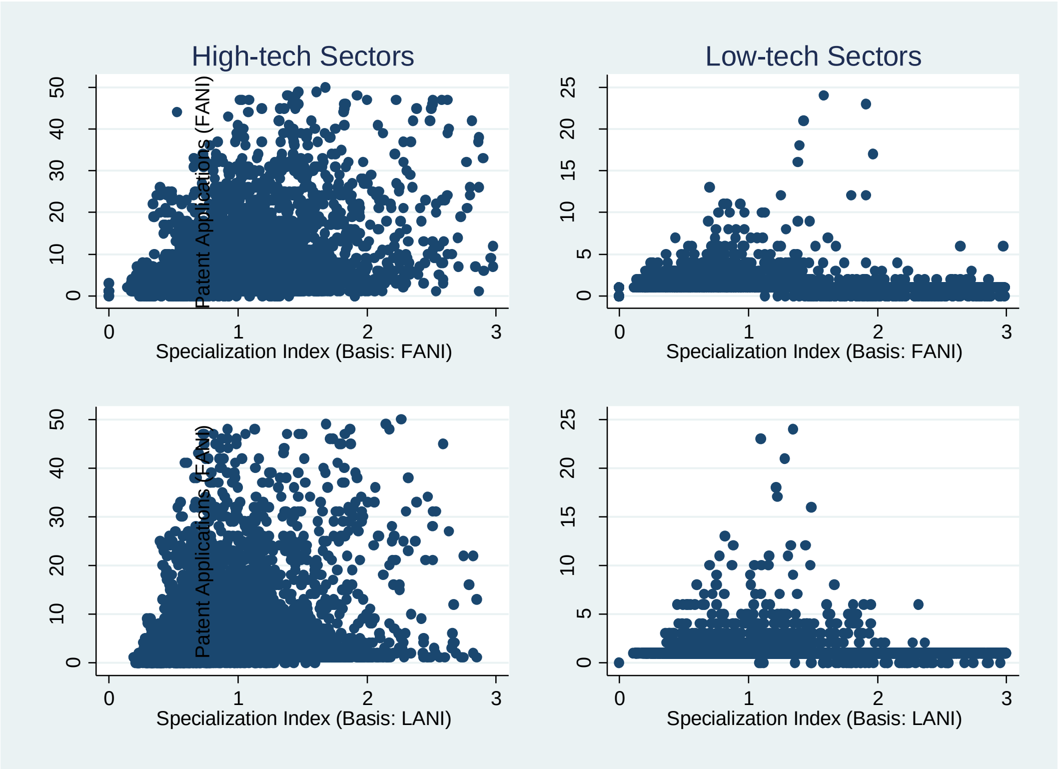


Figure A2: Influence of sectoral heterogeneity on the specialization effect



Note: The definition of high-tech sectors coincides to the OECD classification and contains NACE codes 24, 29, 31, 33, 34 and 35. See Hatzichronoglou (1997). Following the OECD definition, NACE codes 15 to 22 are regarded as low tech sectors.

Table A4 *Correlation matrix*

	RTA_F~_r	RTA_L~_r	WZhigh~e	divers~e	studie~e	diff_c~r	hig~fani	hig~lani	higher~n	eduWZ	gewerb~r	auto	gesund~x	ln_fla~e	capita~r	RTA_r_~r	d~pate~r	eduWZ_~r	studie~r
RTA_FANI_r	1																		
RTA_LANI_r	0,4483	1																	
WZhigh_RTA	-0,2581	-0,1665	1																
diversific~e	0,2702	0,4252	-0,0839	1															
studierende	-0,1223	-0,159	0,0311	-0,3901	1														
diff_cumPa~	-0,063	-0,0453	0,3866	-0,2389	0,0924	1													
higherO~fan	-0,0491	-0,2141	0,1345	-0,6196	0,2454	0,2653	1												
higherO~lan	-0,2079	-0,1731	0,1586	-0,6539	0,2888	0,3371	0,8412	1											
higherOrde~	-0,2684	-0,2666	0,0554	-0,7008	0,3073	0,2082	0,8747	0,8984	1										
eduWZ	-0,1668	-0,1087	0,414	-0,0993	0,1189	0,2642	0,1125	0,1385	0,0771	1									
gewerbeste~	-0,0849	-0,1775	0,0206	-0,3596	0,4587	0,1014	0,2087	0,2484	0,2526	0,0716	1								
auto	0,0861	0,1977	-0,0281	0,4041	-0,1995	-0,1073	-0,1168	-0,1558	-0,1466	-0,02	-0,4324	1							
gesundheit~	-0,0556	-0,0596	0,0171	-0,1304	0,3846	0,0389	0,0333	0,0547	0,0491	0,0722	0,021	-0,0656	1						
ln_flaeche	0,0496	0,0934	-0,011	0,1659	-0,2596	-0,0077	-0,0489	-0,0746	-0,0629	-0,0459	-0,5075	0,3426	-0,1127	1					
capital_ror	-0,1163	-0,0719	0,0155	-0,2257	0,3227	0,1515	0,0608	0,1086	0,1017	0,1729	0,2347	-0,2259	0,1578	-0,1443	1				
RTA_r_nach~	0,474	0,7293	-0,3044	0,2768	-0,0325	-0,1042	-0,1859	-0,191	-0,2165	-0,1675	-0,12	0,115	-0,0265	0,0837	0,0881	1			
divers_pat~r	0,1762	0,304	-0,0567	0,5959	-0,0428	-0,1428	-0,3865	-0,4092	-0,451	0,0448	-0,2176	0,2096	-0,0189	0,1409	0,1675	0,4451	1		
eduWZ_nach	-0,263	-0,2009	0,5552	0,0212	-0,0517	0,1892	0,0147	0,027	-0,0224	0,4783	-0,0523	0,0849	0,0086	0,0593	-0,0085	-0,268	-0,004	1	
studierend~	0,0019	-0,0956	0,0065	-0,1361	-0,1679	0,0476	-0,037	-0,0377	-0,0487	-0,0699	0,308	-0,2103	-0,2874	0,0387	-0,208	-0,1936	-0,4542	0,0244	1

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