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Title: Technology Sourcing by Foreign-owned MNEs in Germany –An analysis using patent citations

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Preliminary paper - Please do not quote.

Technology Sourcing by Foreign-owned MNEs in Germany –An analysis using patent citations

Abstract

This paper presents a preliminary examination of technology sourcing and knowledge localisation in the context of Germany. . We use US patent citation data to examine the technology sourcing activities of foreign-owned multinational firms located in Germany over the 1975-1995 period. Particular attention is given to the age profile, the home-base augmenting/exploiting characteristics of such activity and the degree to which local sourcing might be deemed regionally bounded. While regionally bounded activity is seen to depend upon the technological specialisation of foreign firms, a strong relationship exists between the technological specialisation of the indigenous sector and inter-regional sourcing by foreign firms.

Introduction:

Technology and the role that technology has played in the development of the Multinational Enterprises (MNEs) is a source of great interest in the scholarly community. While the idea that the overseas subsidiaries of MNEs engage in technology seeking activities is not new (Dunning, 1958), until quite recently, theory development and systematic evidence of this phenomenon was lacking. Until the late 1980s, the accepted rationale for the MNE was explained in terms of transaction costs and the desire to internalise the so-called ownership advantages of the firm. Subsidiaries were viewed as mere recipients of the technologies developed by the parent firm and their role was to adapt this knowledge to suit the tastes of the local market. While some authors drew attention to the possibility of subsidiary activity evolving through time, evidence presented in support was greeting with skepticism and seen as being against the dominant momentum that centralised high value-added or technological activities within the parent firm (see for example Pearce, 1989).

Paralleling developments in the literature on technological change and the theory on firm activity more generally, a new point of departure has been heralded in the International Business literature in the last decade and a half. The new approach has drawn heavily on the evolutionary view of the firm and industry (Nelson and Winter, 1982) and re assesses the rationale for the MNE and the precise role played by the subsidiary. Recent investigations of the MNE adopt a broader definition of technology, viewing it as a path dependent, corporate learning process. As such, the concept is employed to encompass all aspects of the organisation of production. Viewing the MNE as a *repository of knowledge*, scholars focus attention on the pressures faced by firms when trying to maintain and continuously upgrade their technological know-how. The MNE is believed to offer a superior way of organising technology activities across it's dispersed but interconnected international network. The centripetal characteristics of particular locations and the relevance of geographic proximity have emerged as central issues in investigating the technology sourcing activities by MNEs.

Despite this growing interest most attempts to evaluate hypotheses pertaining to such phenomena have been focused on the US. This in turn means that our knowledge of this issue is somewhat restricted. The focus of this paper is to contribute to our understanding by examining technology sourcing in Germany, a prolific source of technological development throughout the last century and an important European destination for many Multinational Enterprises.

Germany provides a unique testing bed for issues pertaining to technological activity since firms located in this country are important global players on the technology front and the country's strong research infrastructure renders it one of Europe's key locations for science and technological development. In addition, policy has a long tradition of emphasising the science-industry interface in this country, which has resulted in the creation of a world-renowned scientific and technological infrastructure, which aims to promote such linkages. Despite its prominence and its distinguished history of technological leadership, Germany has received comparatively little attention from analysts of the MNE. This paper represents a preliminary attempt to rectify this shortcoming. This paper is divided into four sections. Section 1 outlines some of the empirical literature on technology sourcing that use patent citations and highlights some of the main findings of this research. Section 2 discusses some of the issues surrounding the use of this data in the examination of issues pertaining to technology activities of firms. Section 3 reports the regional characteristics of technological sourcing by foreign firms located in Germany and finally in section 4, we discuss some of the conclusions from this preliminary examination and suggest the potential route that future research might take.

1. Technology sourcing by MNEs – Evidence from patent citations.

Cantwell (1989; 1992; 1993) played a pivotal role in suggesting that firms transcend the limitations of national technological specialisation to take advantage of alternative technologies being developed abroad. However, empirical evidence has been somewhat 'fragmented and contradictory' (Frost, 2001, p.103). Much of the research that supports this asset-seeking thesis is based on case studies (oftentimes of Japanese MNCs in the U.S.) with the consequent problems of generalisability and sample selection bias. Larger sample studies find mixed support for the hypothesis that MNCs locate overseas to tap into local sources of knowledge and technological know-how.

Using patent citations, a number of studies have recently re examined this issue. Almeida (1996) presented the first empirical investigation of technology sourcing by foreign firms in the U.S. This study is based on the semiconductor industry and in addition to employing the Jaffe et al. (1993) methodology, also adopts a *historical* approach in analysing the citation activity of 22 U.S.-based foreign-owned subsidiaries. Employing this novel approach, the author traces the knowledge trail by examining all prior art referenced in each fabrication and design patent granted to these subsidiaries. As such, it might be classified as being a *backward looking* or *historical* approach to the examination of inter-firm knowledge activities. The approach is in marked contrast to that employed by all other studies using citation data to examine spillover activity. Most empirical investigations of this phenomenon have adopted the methodology presented by Jaffe et al. (1993) which uncovers the knowledge trail by identifying all citations received by each granted patent *ex post*. This methodology is referred to in this thesis as *forward-looking.* The empirical examination reported in this paper adopts Almeida's historical approach and the merits of this approach are discussed in section 2.1 of this paper.

Almeida (1996) examines technology sourcing by multinationals at a time of heightened U.S. concern that foreign firms (particularly Japanese) were locating in the U.S. to access local technological expertise thereby diluting U.S. technological advantage within certain fields[1]. The authors reported how the subsidiaries of foreign MNCs located in the U.S. were engaged in high value-added R&D activities and absorbed know how from the U.S national system of innovation. Almeida contributes to the debate by investigating the extent to which foreign-owned semiconductor subsidiaries accessed but also contributed to the local (regional or country) knowledge pool in the U.S.

Results demonstrate that the knowledge building practices of these firms are localised and within regions, foreign firms not only learn more from local sources but do so to a greater extent that their domestic counterparts. Foreign subsidiaries are also seen to contribute to the host. This is evidenced by the fact that foreign-owned patents are cited locally to a greater degree than would be expected given the spatial distribution of technological activity. This finding is significant for U.S. regions but weaker at the country level (*ibid*. p. 161). Finally, by using RTA indices, this study investigates whether foreign firms locate their technological activities overseas in areas of home country disadvantage. For most countries (including Germany, France, Italy and the U.K.), evidence is presented in support of this thesis. In the case of Japanese subsidiaries however, results suggest that the U.S.-based technological activities of these firms lie in areas of local relative disadvantage (*ibid.* p. 162)

[1] Earlier evidence presented by Kogut and Gittelman, (1994) for the biotechnology and electronics sectors supported this fear.

In a recent paper, Frost (2001) presents a broader examination of foreign-owned technological activity within the U.S. His study uses citation information contained in a total of 10,589 patents distributed across 33 technologies that originate from the technological work undertaken by the U.S.-based subsidiaries of foreign MNCs. The time period covered by the study is 1980-1990. The central tenet of the investigation is that the extent to which subsidiaries draw on local versus home knowledge sources will be determined by a plethora of subsidiary characteristics. These include the nature of the innovation undertaken by the subsidiary at the host (i.e. adaptive versus creation); the relative strength of the subsidiaries technological capabilities; the relative scale of technological activity; age of the subsidiary and finally, the technical presence of the parent firm at the host location. Controlling for pre existing concentrations of patenting activity and unobserved differences in patterns of knowledge sourcing across technological fields, results support the hypothesis that the geographic sources of subsidiary activity are influenced by the characteristics of subsidiary activity. Larger (measured by total patenting activity) subsidiaries are more likely to source locally. Interestingly, the magnitude and significance of the coefficient on the technological capability variable (proxied by the share of company patents generated by the subsidiary) increases as the analysis moves from the national to state level. This suggests that sub national (or regional) sources of innovation act as particularly important bases for subsidiary technological capabilities (*ibid.* p. 115)

In contrast to what one might expect, results from this analysis suggest that older subsidiaries are less technologically embedded in the host (*ibid*. p. 117). This suggests that older subsidiaries are more likely to draw from the technological base of the home country rather than the locally. Finally, lending support to Cantwell (1992), the research demonstrates that citation to the home country occurs in areas of local technological disadvantage.

As noted above, the degree to which these results are representative of large firm technology activity at locations outside of the US has been little explored in the literature. This paper seeks to address this gap.

2. Methodology – Using patent citations

Although citation data is a relatively new technology indicator, it is clear from the above discussion that a growing number of scholars have discovered the attributes of this proxy for examining issues pertaining to corporate technological activity[2].

The reliability of using citations as an indicator of technology spillovers between agents has nonetheless been questioned. In addition to the citations that the inventor is obliged to, additional citations may be included for a number of different reasons. First, out of legal concerns. To avoid infringement, a risk-averse patent lawyer may include additional citations that might not necessarily be considered 'prior art' by the inventor but are considered vital for staving off potential legal battles. Second, citations may be included that are referred to as 'after-the-fact cites'. In such instances, knowledge of 'relevant prior art' may be discovered by the patentee *ex post* but then added to the list of citations. The third category is referred to as 'teaching cites'. These include inventions, which while not directly drawn upon by the inventor in the process of exploration are nonetheless viewed as *basic* to this process. Therefore, they are also included in the list of prior art. Finally, the patent examiner may add any number of additional citations that he deems relevant to the invention. Because of such additions, patent citations have been described as a *valid but noisy measure of spillovers* (For further discussion, see Jaffe et al. 1998 and Jaffe et al. 2000).

Criscuolo et al. (2001, p. 9) argue that in the context of large multinational firms, it is reasonable to assume that a large proportion of citations will be listed by the inventor thereby minimising the amount of noise in the data. Since patents are in the public domain and readily accessible, the authors suggest that it is highly probable that professional R&D laboratories would have identified all existing patents in their area of technological search.

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[2] It has also been demonstrated that citation frequencies indicate social value or in other words, the quality and importance of various inventions. For example, in an analysis of inventions that emerged during the development of computed tomography (CAT) scanners, Trajtenberg (1990) reports that patents covering inventions of greater social value were cited significantly more frequently in subsequent patents than inventions of lesser value. Taking a much wider sample of U.S. and German patented inventions, Harhoff et al. (1997) confirm the correlation between social value and citation rates.

Regardless of who actually adds the citations, the position taken in this analysis is that *all* references to prior art are important in the investigation of spatial knowledge flows. Since additional citations represent all influences (conscious or otherwise) on contemporary invention, they add objectivity to the analysis of spatial knowledge flows. Their inclusion therefore protects against any bias that might emerge in favour of the 'localisation' of knowledge flows. Jaffe et al. (1993, p. 596) suggest that when ones objective is to study the overall spatial characteristics of technological development, the origin of subsequent invention may be considered inconsequential so long as it occurs at a certain location

Consequently, patent citations are used in this study to facilitate an in depth analysis of technological exchange at regional level in Germany. All inventions (as proxied by patents and the citations contained therein) are classified under one of 401 patent classes by the USPTO and the research facilities were categorised according to ownership (i.e. foreign versus indigenous)[3]. In the University of Reading's patent database, the patent classes have been further allocated into one of 56 groups of common activity. To facilitate the geographical analysis of this data, the location of invention was extracted from each patent document and a revised Nomenclature of Territorial Units for Statistics (or NUTS) code was attributed (see Noonan, 2002 for further discussion of this data).

2.1 Forward versus historical based approaches

In general, the studies to date have taken particular groups of frequently 'cited' patents (usually within a particular technology family) and analysed the citation patterns to these inventions. In adopting this approach, authors have encountered what is referred to as a *truncation bias*. This refers to difficulties encountered when deciding upon the appropriate cut off points for the citation window. Stated simply, in undertaking such analyses, the researcher is confronted with the difficulty of trying to ascertain the correct time frame within which inventions receive their maximum number of citations. Consider Coases's 1937 article for example. This was almost never cited before 1975 but

[3] Depending on the range of applicability, an invention may be allocated into a number of different classifications. In all cases, an invention's primary classification is used in the Reading database.

then cited massively after that date. If one was to fix the citation window at twenty years, one might be tempted to conclude that this seminal piece of work really had little impact upon the academic work that followed. Of course, we know that this was not the case – it just took the academic world a little longer to recognise the significance of this piece of work.

In terms of invention, identifying the window within which maximum citation activity is likely to occur is extremely challenging. It is virtually impossible to be totally confident that what may be perceived to be relatively unimportant inventions today (i.e. as evidenced by low citation activity) will not become hugely important in the future. Hall et al. (1998) highlight the skewed nature of the distribution of patent citations. Examining the citations made to the inventions of 4800 publicly traded manufacturing firms 1975-1995, the authors draw attention to the fact that citations frequently continue more than 10 years after the original patent is granted.

In contrast to the aforementioned traditional citations literature, this analysis echoes the approach undertaken by Almeida (1996). This analysis commences with the 'citing' patent, which means that this approach is backward looking and historical. This is useful because it means that the number of citations is fixed and definitive at the point of issue rather than being forward-looking and open-ended as was the case in previous studies.

As can be seen from Figure 1, the distribution of these 'citing' patents is much less skewed than the distribution of 'cited' patents (evidenced in Hall et al. 1998). The modal values are 3 and 4, which is in marked contrast to the equivalent for cited patents (where the modal value is zero).

FIGURE 1 HERE

3 The Regional Characteristics of Technology Sourcing

In this section, we examine the regional characteristics of technological sourcing by foreign firms. Prior to this examination, Table 1 reports the regional origin of the patent citations. By examining the location code of the original citing patent we can ascertain the region from which each cited patent (or citation) emanated. This is then compared with the distribution of foreign-owned patents (i.e. citing patents).

TABLE 1 HERE

Reflecting the regional distribution of total (citing) patents granted to large foreign firms located in Germany between 1969-95 (see Cantwell and Noonan 2002), it is unsurprising to find that the majority of citations emerge from six of the sixteen Bundesländer. Of these, approximately 52 percent of citations originated from the research activities in the two regions of Baden Württemberg and Nordrhein-Westfalen. The majority of patent citations are referenced by inventions undertaken in Baden Württemberg (31.8%) and Nordrhein-Westfalen (20.9%). It is interesting to note that Nordrhein-Westfalen and Hessen cite a greater percentage of prior art than the distribution of citing patents might suggest. While the former hosts 19.1% of total foreign-owned patents and these patents are associated with 20.9% of all citations, the latter hosts 13.9% and is associated with 14.7% of all citations. In other words, the types of technologies being developed in these regions tend to be cited relatively frequently. As such, they are important elements of the German research environment.

3.1 Sourcing of technological knowledge

As noted above, traditional analysis in the International Business field emphasises the central role played by the parent company in the development of technological know-how. According to this literature, any incidence of technological activity located overseas was considered to be adaptive in nature and was heavily reliant on the centralised knowledge base of the organisation (i.e. the R&D laboratories located in the parent firm). This type of overseas technological development has been referred to as Asset Exploiting R&D (Dunning and Narula, 1995) or Home Base Exploiting (HBE) activity (Kummerle, 1997). If this thesis were correct, one would expect to see technological expertise disseminating in an outward direction from the parent company to all overseas subsidiaries. Technologies are developed at the home base and then transferred to the subsidiary network. Using the patent citation activity of foreign firms located in Germany as a proxy for technology communication between these subsidiaries and their parents, one would therefore expect to observe that the majority of the citations lead us back to the parent firm. If overseas technological activity is merely *exploiting* what has been developed within the research labs of the parent firm, one would expect to observe that the majority of citations reference the prior technological activities of the parent. The results of this examination are reported in Table 2.

TABLE 2 HERE

It is apparent from these findings that over the 1975-1995 period, foreign firms located in Germany sourced approximately 29 percent of their technological knowledge from the home country of the parent firm. This suggests that the technological activities of foreign subsidiaries located in Germany are not heavily concentrated in HBE-type activities. In line with the more contemporary IB literature that relegates the role of the parent firm in the technological activities of overseas subsidiaries, it is interesting to note the proportion of knowledge sourced at local level (19%) and the high proportion sourced from other foreign countries (approximately 52 percent)[4]. This suggests that the technological endeavours of these firms may be more accurately referred to as strategic asset seeking (Dunning and Narula, 1995) or home base augmenting (Kummerle, 1996) – type

[4]Controlling for the global distribution of patenting, of course one might expect this proportion to be less striking. Given the central location of Germany within Europe, one might expect extensive inter-national citation across bordering European countries. This would support Jaffe and Trajtenberg's (1996) study of citations to US-based invention. They found that the extent to which patents granted to foreign residents were likely to cite U.S. patents depended upon geographic and cultural proximity.

activities. Rather than merely adapting the extant technologies of the parent firm (or acting as a substitute for activities the MNE may have wished to undertake at home (Zander, 1999), these subsidiaries seek to enhance the technological base of the parent firm by developing completely new (though complementary) lines of search[5]. In addition to drawing from the highly developed local German knowledge base, foreign subsidiaries located in this country also build upon technologies that have been developed at a variety of other international locations.

Although self-citations are a vital element in any analysis of regional development or technological embeddedness across space, it is important to differentiate this type of citation activity when studying potential knowledge interactions within versus between firms (intra versus inter-firm activity). In their study of international knowledge flows, Jaffe and Trajtenberg (1998, p. 11) emphasise this point noting that since self-citations come more quickly on average and are more geographically localised, they bias the study of knowledge localisation in an upward direction[6].

By extracting the proportion of self cites (i.e. cases in which the assignor (or owner) of the cited patent is the same as the citing patent), we arrive at a proxy for technological communication between the subsidiary and the parent (Table 3)[7]. In doing this we find that just 29 percent of total citations to the home country were made to inventions undertaken by members of the corporate group located there. This finding clearly questions the historic importance attributed to the parent firm and confirms the appropriateness of reinvestigating the role played by the parent firm in the technological activities of overseas subsidiaries.

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[5] For further discussion of this literature and why HBA activities are difficult to achieve from the home base, see chapter 3.

[6] Following Jaffe et al. (1993) who interpreted a high proportion of self cites to indicate successful appropriation efforts by the original inventor, Putnam (1997) suggests that self-citations are a reliable predictor of a firm's decision to pay renewal fees on patents that would otherwise expire.

[7]Self-citations capture all references to prior technological activity undertaken by the entire corporate group. This is not a strict measure of citations to the parent firm but rather to members of the corporate group that are located in the home country of the parent firm.

Results from this investigation suggest that while 23% of citations are made to other large firms within the same industry, the majority of citations (48%) to the home country reference the technological activities of other large firms in *different* industries.

TABLE 3 HERE

By once again examining the proportion of self-citations (within the overall citations to the knowledge infrastructures of *other foreign locations*), we find that 4% percent of total citations reference the technological activities of the multinational group in foreign locations. This suggests that the majority of the technologies under development in Germany do not build upon the technological activities of other parts of the international corporate network. This may however reflect activities undertaken by means of external networks (constituting the virtual organisation) at other locations. In referencing the prior inventions of other foreign countries, these firms cite the technological activities of other large firms from the same industry (45%) and other large firms from different industries most frequently (51%).

In terms of the local knowledge infrastructure, it is apparent from these results that foreign firms source almost 19 percent of their knowledge (i.e. 12,580 citations) from the local sources. Considering that the total share of US patents granted to Germany-based technological activity was 8.5 % between 1975-1995 (and 7.8 % between 1963-1995), this is a significant finding. It demonstrates that the propensity of foreign firms to use local sourcing is far greater than what might be expected if one were to follow a random distribution of technological activity. It highlights the importance of the host economy and suggests that (at least across certain technologies), foreign firms are aware of the difficulty of learning from afar and therefore use their subsidiaries to upgrade their technological ability within certain fields of exploration (Almeida, 1996).

A high proportion of self-citations to local invention is apparent in Table 3. This is unsurprising since knowledge creation is a cumulative process, and so builds up within each local context (even if what is being done is largely of an adaptive kind). Care should be taken however when interpreting results where self-citations might constitute almost 50 % of a sample i.e. it is important to differentiate between inter and intra firm activity. Therefore throughout the paper, we make it clear whether self-citations have been included or excluded from the results[8].

It is unsurprising to note that the majority of patents citing local knowledge sources reference prior art that is attributed to the efforts of inventors in the Baden Württemberg region (4.2%). As discussed in Cantwell and Noonan (2002), this region not only hosts the greatest concentration of patenting activity by foreign firms in Germany but is also an important location for indigenous firms, particularly within the transportation technologies. The next most frequently cited region by foreign firms is Nordrhein-Westfalen - the hub of the German chemical industry and the favoured location for indigenous firm technological activity. Foreign firms that locate in this region are highly specialised across the mechanical technologies.

3.2 Age distribution of Technology sourcing

It has been suggested that geographical proximity may be most important for the absorption of recently developed technologies. By ‘recent’ technologies, we mean the further development of both extant fields of research as well as the creation of whole new areas through fusion or novel combination. The more novel (or new) is the technology, the more likely it is that the tacit component constitutes a significant barrier to further development from afar. Knowledge takes time to diffuse due to the difficulties of communicating its inherent characteristics that are frequently quite intimately bound up with context. Cultural barriers to transmission may also impede this. Co-location therefore becomes a crucial prerequisite to the development of these highly tacit technologies. The importance of the tacit component in technological activities is believed to have escalated in recent time due mainly to the growing relatedness of

[8] While other analysts of citation data also make this distinction, the proportion of self-citations generally goes unreported.

technologies which has been largely fuelled by the pervasive qualities of the science based technologies (for further discussion, see Cantwell and Noonan, 2002). Firms that wish to research at the technological frontier in sectors that are non-core to their business must co-locate alongside the international leaders within the particular technological sector or in other words, within the appropriate international centre of excellence.

In marked contrast, geographical proximity is not seen to be as important a consideration in the case of older inventions (Jaffe et al. 1998). Through time, codification of early inventions takes place, which serves to reduce the tacit dimension involved in such activities. This in turn means that these older inventions (or the bases for contemporary invention) can be drawn or built upon, without any need to co-locate.

Following this discussion, we investigate the age profile of the technologies cited at local level. By subtracting the issue date of the cited patent from that of the citing patent, one can ascertain the 'age' of the knowledge being acquired from the various locations. Large differences between the two means that the technological know-how upon which the current inventor builds, was created at a much earlier point in time. In contrast, a smaller age difference signals that more contemporary knowledge is being drawn upon.

Figure 2 reports the results from this exercise. The three location categories are again examined. Part (i) of the chart reports the age distribution for the citations that reference inventions undertaken in the home country of the parent firm. While a considerable proportion of the citations references relatively recent inventions (approximately 29 percent of the citation data reference inventions that were between 1 and 6 years old - modal values equalling 3 and 4 years), the rather skewed nature of this age distribution is nonetheless apparent. It suggests that quite a large proportion of the citations made by foreign firms to home country inventions refer to older innovations and as such supports the thesis that older inventions are more easily diffused across space.

FIGURE 2 HERE

Lower modal values (2 and 3 years) are found for references to inventions occurring in other foreign countries and approximately 40 percent of citations to inventions originating from these locations fall within the 6-year window (see part (ii) of the chart). Relative to the home country therefore, we can conclude that knowledge accessed by these subsidiaries from overseas locations is more recent.

Finally, part (iii) of the chart reports the age distribution of the knowledge being sourced by these subsidiaries from local (Germany-based) sources. The result is quite dramatic. While the modal value drops to 2 years, the proportion of citations that reference prior art within the 6-year window rises to over 50 percent. In contrast to the results in parts (i) and (ii), the distribution is a lot more skewed for local sourcing of knowledge with the vast proportion of citations referencing work that was invented within a 12-year window. This lends further support to the suggestion that Germany is a centre of technological excellence for large foreign-owned firms who are attracted to this location to access and absorb cutting edge knowledge within certain technological areas.

The increase in citation activity that takes place around inventions that are approximately 45-60 years old is also interesting and deserves comment. Although the percentage of citations that fall into this category is quite small, taken together, they exert a significant impact on the overall distribution. Citations to much older inventions highlights the strong historic research base in Germany and points to the path dependent nature of technological development at this location[9]. In other words, although foreign firms primarily locate their R&D at this location to access recent (or frontier-type) inventions, in doing so, they also draw from the country's historic pool of technological expertise[10].

In what follows, I focus solely upon the local sourcing of technological know-how by foreign-owned firms.

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[9] This also highlights continued importance or relevance of older inventions that emanated from this location. In their examination of international knowledge flows, Jaffe and Trajtenberg (1998, p.4) draw attention to the diffusion and obsolescence processes at play in knowledge flow processes. The authors note that 'while the probability that the inventor will know of a given antecedent increases (…) the probability that the antecedent will actually be helpful declines on average'.

[10] The 'older' technologies (i.e. > 40 years) sourced by foreign subsidiaries are concentrated in mechanical technologies – particularly, miscellaneous metal products (14), other general industrial equipment (29), metal working equipment (17), other specialised machinery (28), chemical and allied equipment (16), other instruments and controls (53) and assembly and material handling equipment (20).

3.3 The regional characteristics of local sourcing of technological knowledge

Table 4 reports the regional distribution of all references to the local knowledge base in Germany. As noted above, total citations to local knowledge corresponds to approximately 19% (or 12,580) of the total citations sample. Taking the regional distribution of total citations as an indicator of the relative attractiveness of each region's pool of technological expertise, it is clear that Baden Württemberg and Nordrhein-Westfalen emerge as the most popular regions (accounting for 29 and 25 percent (respectively) of total citations). The type of technological activities taking place at these locations could of course bias this finding. To control for the high incidence of patenting that takes place across certain technologies, the proportion of citations made to each region's technological infrastructure is divided by each region's share of total corporate patents. Allowing for this regional specificity of technological specialisation, it is clear that while two of the six regions attract an expected proportion of total citations (following the distribution of foreign-owned patenting activity), Bayern and Nordrhein-Westfalen receive 50 and 20 percent more citations than one might expect.

TABLE 4 HERE

Prior research suggested that the potential for intra regional technological exchange across generic technology sectors was quite low (Cantwell and Noonan, 2001). Since foreign and indigenous firms tended to specialise across different sectors of technological development at regional level, the regression analysis undertaken rejected the hypothesis that regionally bound inter firm exchange involved interactions across similar sectors of technological development[11]. Evidence pointed to the fact that such forms of technological exchange were more likely to be found at an inter regional level. Of course, this analysis failed to acknowledge the fact that inter firm exchange might well

[11] Of course this did not preclude the possibility that exchange may have occurred across certain technologies. A number of cases were noted in chapter 7 where similar specialisation patterns exist between the two groups of firms. For example, both foreign and indigenous firms are specialized in other transport equipment (47) in Baden Württemberg and Niedersachsen, other general industrial equipment (29) in Nordrhein-Westfalen and Niedersachsen, metal working equipment (17) in Nordrhein-Westfalen, and printing and publishing (26) in Hessen

occur across a range of different technologies that are related to each other by virtue of their being co-developed. Once technology relatedness was calculated and factored into the analysis, the high degree of technological proximity between foreign and indigenous firms became apparent at regional level. This was particularly strong in the case of Baden Württemberg, which suggested the strong potential for regionally bound exchange across a variety of *related* technologies at this location.

Using the citation data set, these findings are revisited once again. By examining the proportion of citations that reference 'within region' research (i.e. the proportion of citing and cited patents that have been attributed the same NUTS regional code), we can ascertain the relative importance of regionally bound knowledge exchange. The results from this investigation are reported in Table 5.

TABLE 5 HERE

The regional locations of the 'citing' patents are listed vertically in this table. It is *from* these regions that references to the knowledge pools of other ('cited') regions emanate. Because the firms located within these regions reference the prior invention that occurred elsewhere, they may be considered to be the benefactors of technologies developed outside of their region. Other authors have referred to these 'citing' regions as *spillover recipients* (Maurseth and Verspagen, 1999, p. 5). The generators of corporate technological expertise are represented along the horizontal of this table (the 'cited patents'). In addition to the six main regions, this list aggregates the remaining 10 regions into 'other' to facilitate an examination of technology sourcing by foreign firms located in these regions. It is clear, for example, that foreign firms located in these 'other' regions source the greatest proportion of technology from the southern region of Bayern (34.4%). Closer examination of the data reveals that it was foreign firms located in the northern regions of Hamburg and Schleswig Holstein that lay behind this figure.

In terms of absolute number of citations to the knowledge pool of the host economy, it is clear that foreign firms located in Baden Württemberg and Nordrhein-Westfalen hold the leading position – they account for 2896 (30%) and 2098 (22%) respectively, of the total references to the knowledge infrastructure in Germany.

The diagonal of this table refers to the proportion of total patent citations that reference activity that takes place within the region. It is clear from these results that a large proportion of knowledge sourcing is regionally bound. For example, if we consider the citation patterns of foreign-owned firms located in Hessen, it is apparent that approximately 42 percent of the local knowledge is sourced from within the region. A further 20.5 percent is sourced from Baden Württemberg. Indeed, with one exception (Nordrhein-Westfalen), it is striking how important Baden Württemberg is as a source of knowledge for foreign firms located across Germany. Next to the more proximate intra regional knowledge sources, Baden Württemberg hosts the most important pool of knowledge for foreign-owned firms located in Germany. Congestion effects in this core region may have forced firms to located elsewhere and tap into the region's knowledge pool from a distance.

The results suggest that in relative terms, knowledge is most regionally bound in the cases of Nordrhein-Westfalen (62%) and Bayern (59 %) and less so in the case of Rheinland Pfalz (21%). By dividing the proportion of intra regional knowledge sourcing by the proportion of total patents attributed to the research activities of each region, we can ascertain the degree to which 'own region' sourcing coincides with what might be termed a *random geographic draw*. This is reported in Figure 3. It is quite evident that in all cases, the 'within region' sourcing is far greater than what might be expected if one were to follow a random distribution of corporate technological activity. This is most noticeable in the case of Niedersachsen where regionally bound citations are far greater than what one might have expected given the proportion of technological activity taking place in this region.

Focusing solely upon inter-firm technology flows i.e. extracting all self citations (Table 6), it is unsurprising to find that the proportion of regionally bound knowledge sourcing declines in all cases – by 18% in Baden Württemberg; 33% in Bayern; 21 % in Hessen, 23 % in Nordrhein-Westfalen and 18% in Rheinland Pfalz and the ranking of the regions alters. While Nordrhein-Westfalen continues to host the greatest proportion of inter-firm technological activity, Baden Württemberg now replaces Bayern as hosting the second highest degree of inter-firm activity. A dramatic decline is recorded in the case of Niedersachsen (35%) and together with the low relative degree of intra regional sourcing in Rheinland-Pfalz, these regions may be described as having an above average reliance on the technologies being developed extra-regionally.

TABLE 6 HERE

Regions that record relatively low degrees of locally bound sourcing may be referred to as *satellite* locations for foreign firms i.e. firms locate their R&D in these regions but source the requisite technological know-how from the knowledge pools of other German regions. Although firms located in Baden Württemberg and Nordrhein-Westfalen source more than 30 percent of their knowledge from within the region, as a general observation, one might conclude that the vast majority of knowledge sourcing by foreign-firms is not regionally bound[12].

The relatively strong reliance on intra regional technology sourcing within Nordrhein-Westfalen persists when intra-firm activity is controlled for. Approximately 39% of inter-firm activity is localised, which suggests that this region might be classified (at least in relative terms) as being *technologically self-contained* within the German context. Firms located in Nordrhein-Westfalen extract additional sources of knowledge from Baden Württemberg (24%). Taken together, approximately 63% of the inter-firm knowledge sourced by firms located in Nordrhein-Westfalen is accounted for flows occurring within the region and between this region and Baden Württemberg. Indeed, the

[12] Given that the greatest distance in Germany (from Northeast to Southwest) is approximately 600 miles and this country boasts a highly developed research infrastructure, this result is once again unsurprising.

importance of Baden Württemberg becomes even more striking when focusing solely upon these inter-firm technological activities. With the exception of Nordrhein-Westfalen (and Baden Württemberg) itself, it is apparent that that firms located in all other regions source a greater percentage of technological know-how from the Baden Württemberg region than they do from their 'home' regions - Bavaria - 28%; Hessen - 33%; Niedersachsen - 43% and Rheinland Pfalz - 32%. As such, the knowledge reservoir embedded within the firms and infrastructures of Baden Württemberg may be viewed as an important centripetal force for attracting inward investment in R&D in Germany[13]. Substantial reliance (i.e. > 20%) on extra regional sources is also apparent in the cases of Baden Württemberg and Bayern (whose firms access a significant amount of knowledge from firms located in Nordrhein-Westfalen) and Rheinland-Pfalz, where firms interact with their counterparts in Hessen when sourcing knowledge.

4. Characteristics of intra versus inter regional sourcing of knowledge

This section investigates the degree to which the regionally bound sources of technology for foreign firms are related to local areas of strength. Technological specialisation as indicated by patent citations is measured by the Revealed Technological Advantage (RTA) index[14]. We refer to this as the citations RTA (RTA^*) calculate it as:

$$RTA^* = \left. \frac{P_{ij}^*}{P_{iw}^*} \middle/ \frac{\sum_i P_j^*}{\sum_i P_w^*} \right.$$

Where: i = Technology 1…56

[13] Since Baden Württemberg is the source of much technological knowledge for foreign-owned firms within Germany, they may be seen to be forging *common architectural conceptions of knowledge* between this region and their regional homes in Germany (Henderson and Clarke, 1990).

[14] This technique was first applied by Soete (1987) and subsequently developed *inter alia* by Cantwell (1989, 1993). It is a widely used proxy for technological specialisation.

j = Region 1….6

P* = Cited patent

P_w* = World citations[15]

Two different 'Citations RTA' indices are calculated. The first captures the technology sources tapped into by foreign-owned firms located within a region (i.e. intra regional sources or in other words, the activities undertaken by 'insiders'). The second captures the technology sources availed of by foreign-owned firms located outside of any particular region (i.e. that undertaken by 'outsiders'). This differentiation is made as a prerequisite to examining the characteristics of intra versus inter regional communication within technological space. Results from this exercise are reported in Table 7[16].

Looking at the results of the Pearson correlation, it is clear that little relationship exists between the profiles of intra versus inter regional technology sourcing. In other words, the technologies being accessed by firms located within a region are in different fields to those being accessed by firms located outside the region. The one exception is Hessen, which is located in the centre of German and borders the five other regions. Regardless of location, firms seem to tap into similar lines of technological expertise embedded in this region. Technologies accessed by both 'insiders' and 'outsiders' are spread across all macro groups - mechanical technologies (14, 29, 27 and 31), chemical technologies (6 and 9), transport technology (43) and electronic technology (36)[17].

[15] World citations are represented here by those emanating from the technological activity of foreign-owned firms in Germany.

[16] In contrast to the methodology used in Cantwell and Noonan (2002), technology sectors that record low numbers of citations are not omitted from this analysis. As noted above, the proxy for 'world' citations in this formula is generated by the citation activity of foreign firms in Germany only. This 'citations RTA' therefore, captures each region's relative attractiveness within the German context (and not within the global context, which is what the original RTA captured).

[17] Examples where both 'insiders' and 'outsiders' tap into the same fields of technology are of course evident from Table 7. In the case of Baden Württemberg, for example, although the sourcing indices are in general uncorrelated for these two groups of firms, they both source know-how within electronic technologies 35, 36 and 39 from this region.

TABLE 7 HERE

To ascertain whether the technology sourcing profiles of these ‘insiders’ and ‘outsiders’ are related to technology specialisation profiles of foreign and indigenous firms located in each region, two regressions are undertaken for each region:

(1) $RTA_j^* = \alpha + \beta\ RTA_{fj} + \lambda\ RTA_{gj} + \varepsilon_i$

(2) $RTA_{jo}^* = \alpha + \beta\ RTA_{fj} + \lambda\ RTA_{gj} + \varepsilon_i$

where: j = Region 1…6

i = Technology 1….56

α, β and λ are the regression coefficients

ε_i = a residual

RTA_f = Technology specialisation of foreign firms (1969-95)[18]

RTA_g = Technology specialisation of indigenous firms (1969-95)

RTA_j^* = Technology sourcing profile for firms located in region j (1975-95

RTA_{jo}^* = Technology sourcing profile for firms located outside region j that source technologies from region j (1975-95)

The results from these regressions are reported in Table 8. These results suggest that while intra regional sourcing by foreign-owned firms (i.e. the ‘insiders’ within each

[18] For discussion of the RTA indices for foreign and indigenous German firms 1969-95, please see Cantwell and Noonan (2002).

region) tends to follow the local technology specialisation patterns of foreign-owned firms, sourcing by firms located outside the region (i.e. the 'outsiders') tends to emulate the specialisation profiles of indigenous German firms within each region. This former result may be unsurprising given the fact that a large percentage of intra regional citations are *self cites*[19]. However, even if all incidences of self-citation are omitted from the sample and the regressions re run, it is clear that (with two exceptions in both cases) these relationships generally continue to hold (see Table 9)[20].

TABLES 8 and 9 HERE

The patterns of local technology sourcing that emerge from this analysis are represented in Figure 4.

FIGURE 4 HERE

4. Conclusions

This paper presented a descriptive analysis of the technology sourcing activities of foreign firms located in Germany between 1975 and 1995. From this initial examination of the citation activity of foreign-owned firms, a number of issues emerge. First, relative to a random distribution of international patenting activity, it is clear that foreign firms' source a high proportion of knowledge from this host country (approximately 19%). This highlights the importance of Germany as an international source of technological know-

[19] Approximately 43 % of the 9442 citations under study are self cites and of these, approximately 78 percent are regionally bound.

[20] As can be seen in Table 9, there are a number of exceptions to this overall finding. While the former result (i.e. intra regional citations are correlated to the technology specialisation of foreign-owned firms at regional level) holds in all regions but Nordrhein-Westfalen and Rheinland-Pfalz, exceptions to the latter result (i.e. that citations from outside the region are correlated to the technological specialisation of indigenous firms) are found in the Niedersachsen and Bayern regions.

how. Further support is found when one considers the nature of technological activity undertaken at this location. Since relatively few citations lead back to the knowledge pool of the parent firm, the technological activities undertaken in Germany may be categorised as *home base augmenting* - rather than building upon prior research of the parent, new lines of technological search are pursued at this location. The age profile of the knowledge sourced from this location provides further evidence. In contrast to that sourced from the home location and indeed from other foreign locations, technologies accessed locally in Germany may be classified as 'younger'. This underscores the importance of physical presence at locations that host cutting edge research – because the tacit component is likely to be higher across recently developed technologies, firms must locate within the appropriate international centre of excellence to *breath in the air of innovation*.

While a high degree of regionally bound sourcing is reported in section 3, this was essentially due to the inclusion of self-citations. Removing these from the analysis reduced the overall degree of knowledge localisation at regional level and the regional rankings changed. While intra region sourcing continues to be relatively strong within Nordrhein-Westfalen, Baden Württemberg replaces Bayern as the second most important location for regionally bound inter-firm activity. Attention was also drawn to Baden Württemberg since firms located in Bayern, Hessen, Niedersachsen and Rheinland-Pfalz source a greater proportion of technology from their counterparts in this region than they do locally. A very low reliance on intra regional sources of inter-firm technology exchange occurs in Niedersachsen and Rheinland Pfalz, which seems to support the suggestion that firms use these locations as satellite positions from which to access knowledge elsewhere in Germany.

Examining the nature of technology sourcing by foreign firms, the regression analysis suggests that while indigenous firms provide knowledge that can be accessed from any part of Germany, knowledge provided by the foreign sector itself seems to be more regionally bound. A number of potential explanations lie behind this finding. For example, it is possible that indigenous firms perceive the foreign-owned firms located within the same region as a competitive threat and are therefore slow (or unwilling) to allow them access to their in-house knowledge infrastructures. In contrast, foreign-firms that seek to tap into indigenous knowledge from afar (i.e. outside the region) are not seen to pose as large a threat. This focuses attention upon the *emitting capacity* of indigenous firms and highlights how this can be used to weaken (or indeed prevent) technology flows between firms[21].

Although earlier research has noted how the degree of inter-firm knowledge spillovers (or technology interaction) depends upon both the nature of the technology and the *absorptive capacity* of recipient firms, the importance of the *emitting capacity* in such contexts was not discussed. This latter concept relates to the producers of knowledge and their ability to successfully communicate this knowledge to the outside world. The quality of the knowledge transfer process is seen to be highly dependent upon such considerations. Just as firms display high variation in their absorptive capabilities, they also record substantial differences in their ability to communicate with agents lying outside their organisation[22]. Cohendet and Meyer-Krahmer (2001, p. 1575) further explain how this emitting capacity may be associated with *intentional selectivity* on the part of the firm:

> 'The producer of knowledge has emitting capacities. An agent producing new knowledge will generally operate a selection between communities: on the one side, he will consider to which communities the new knowledge is addressed, and on the other side, whose communities that he chooses to exclude'

The authors (*ibid*, p. 1584) explain how firms that provide assistance to their strategic partners (through investment in knowledge sharing routines, for example) are thereby engaged in a process of deliberately enhancing the absorptive and emitting capacities of their partners:

> '….In other words, the management of the technology process is essentially bi-directional. What matters is more the co-evolution of the

[21] This is consistent with the fact that one of the major weakness within the German system is the relatively poor linkages that exist between indigenous industries (Temple, 1998, p. 275).

[22] Of course the codified element of the newly created knowledge that is reported within the patent document is publicly available, but successful replication (and understanding) of this knowledge requires the replicating firm to establish contact with the highly complementary tacit component of this knowledge. His ability to do this is first and foremost determined by the *emitting capability* of the patentee (or owner of the knowledge).

> mutual absorptive and emitting capacities between partners, than the mere observation of the technology flow between an emitter and a receiver'

Results from the citation analysis may be interpreted in the context of this contribution. Since the technologies draw on by foreign firms do not reflect local technological expertise of indigenous firms, one might conclude that a co-evolution of the *mutual absorptive and emitting capacities* between large foreign- and German-owned firms has simply failed to be developed at regional level in Germany. In marked contrast, these capabilities appear to have successfully amassed between the large foreign-owned firms. While it is beyond the remit of this thesis to adequately examine this issue in further detail, one might suggest that it reflects the mature stage of regional technology clusters within Germany. Rather than attributing the dynamism of regional technology clusters to the expertise of large indigenous firms (as has tended traditionally to be the case in the literature), one might reassess this idea and acknowledge the role played by the foreign-owned sector in such considerations. At least within the German context, the results from this analysis suggest that the knowledge embedded within the foreign-owned sector is what drives the regionally bounded technology activity of foreign-owned firms within these clusters.

In addition to the possibility that indigenous firms view foreign firms as constituting a threat within the region, perhaps foreign-owned firms manage to communicate more effectively with one another since they are faced with similar sets of issues. Operating as subsidiaries of larger companies and being located in a (relatively) unfamiliar environment, it is likely that they are confronted with (broadly) similar sets of concerns – how to deal with local laws and legislation; challenges - how to access the local networks and infrastructures and opportunities. They share the common goal of knowledge seeking activity and may be seen to employ a common framework that enables them to operate within the German environment. They therefore manage to simultaneously build both their absorptive and emitting capacities at local level. In a similar vein (and drawing on Henderson and Clarke (1990)), Phene and Tallman (2002) refer to the importance of cluster specific *architectural knowledge* that:

> (…) develops through common experiences, regular formal and informal interaction, exchange of personnel, alliances, buyer and supplier relationships, personal friendships and a variety of other economic and social relationships. By providing similar concepts of 'how the world works' to firms in a region, shared architectural knowledge makes the exchange and interpretation of component or technical knowledge easier.

While the authors emphasise the varying nature of this *architectural knowledge* across different national clusters (owing to language differences, cultural and ideological concerns (*ibid*. p.6), we suggest that such variations may also exist within a national context - but between the foreign and indigenous firm groupings at regional level. Although these German-owned firms are multinational enterprises and have exposure to international business, their activities are greatly influenced by their common domestic business culture/infrastructure. In other words, through time, these firms are likely to have developed shared meanings about business; technology and the indigenous/foreign divide within the local market.

Because they are less likely to have developed similar sets of shared meanings with their foreign counterparts from an early stage (and accepting that this constitutes a foundation stone for deeper inter-firm interaction), one might suggest that indigenous firms thereby reduce the possibility of creating networks that facilitate intra-regional exchange[23]. In doing so, they (intentionally?) fail to co-develop the capabilities needed to interface with their foreign neighbours across the more tacit dimensions of technological activity that exhibit a distinctly regional character.

These results may also be consistent with the notion that foreign firms locate within particular regions to facilitate interaction within the indigenous *Mittelstand* sector. Mny authors have highlighted the importance of this sector within the technology/innovation domain in Germany. Therefore, rather than seeking explanations through foreign firm interaction with their (large firm) German counterparts, perhaps interaction with indigenous firms takes place at this level.

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[23] Sternberg (2000, p. 111) reports a similar finding in the case of regional research institutes in Germany. In his survey of intra and inter-regional linkages between these institutes and foreign firms, the author finds that cooperation with foreign enterprises in on average quite rare.

While the intra-regional picture suggests that large firm interaction is dominated by technology flows between foreign-owned firms themselves, the analysis at inter-regional level points to the potential for inter-firm flows between foreign and indigenous multinational firms. This is consistent with the recent conceptualisation of the *learning region* presented by Boekema et al. (2000). The authors conclude that the *learning region* refers to plural 'regions' rather than to any singular region and emphasise that a high level of mutual learning between regional agents (i.e. inter regional exchange) is what characterises economically successful regions. Following this, it is clear that while large indigenous firms do not constitute the most proximate source of technological know-how for foreign-owned firms within the regions, their technological expertise is nonetheless an extremely important input into the knowledge activities of these firms. Perhaps, the types of technologies sourced from the large indigenous firms are more easily communicated across space. A more micro examination of the nature of these inter-regional inter-firm technology flows is one potential path for future research.

Tables and Figures

Figure 1 Distribution of Patent Citations

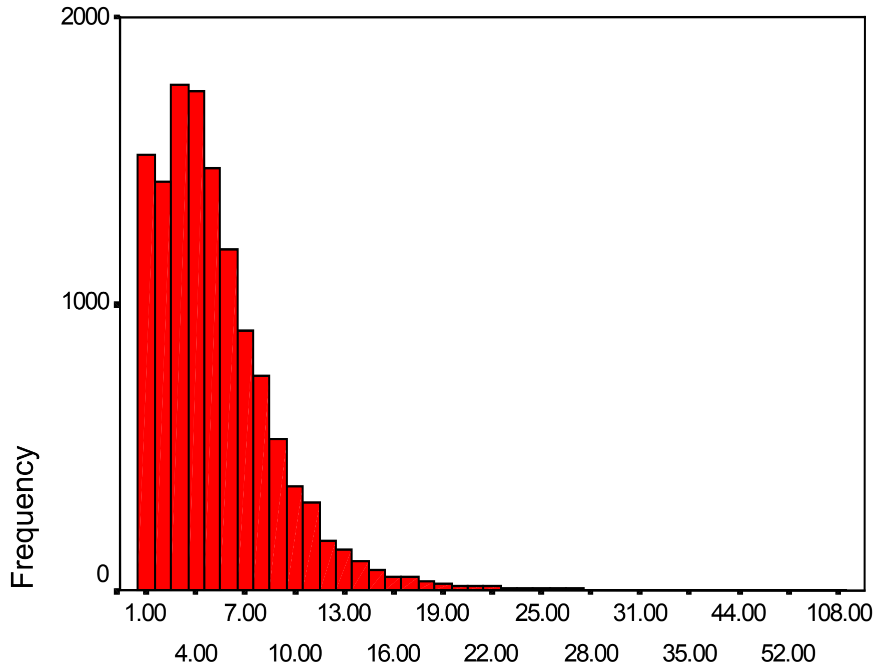
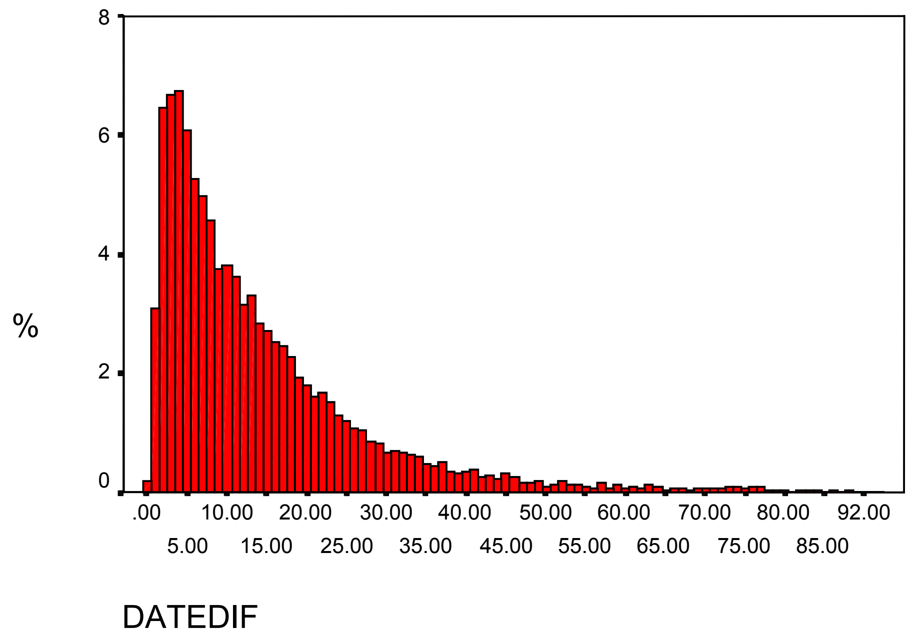
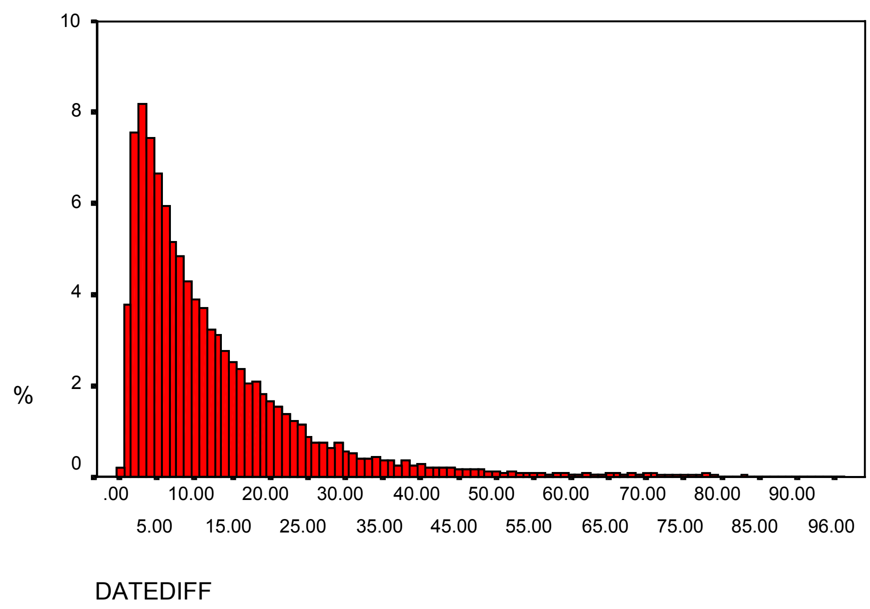


Figure 2 Age Distribution of Technology Sourcing.

(i) Citations to home country



(ii) Citations to other foreign countries



(iii) Citations to local knowledge sources

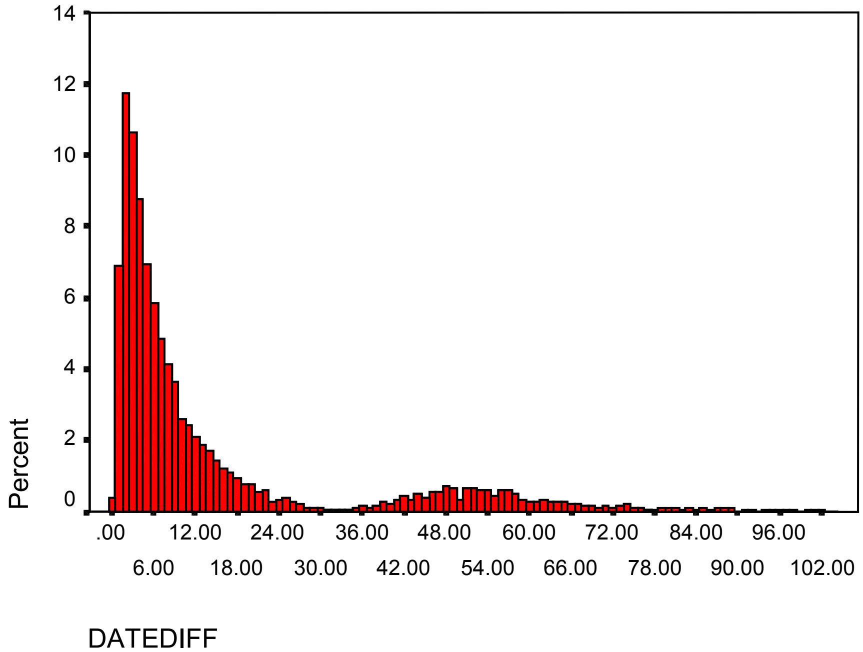


Figure 3 Patterns of Intra Regional of Technology Sourcing (total citations divided by total patents attributed to research within each region).

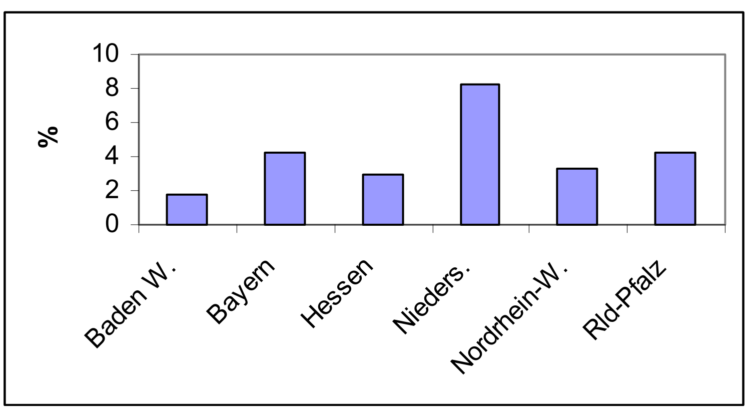


Figure 4 Patterns of inter/intra regional Technology Sourcing

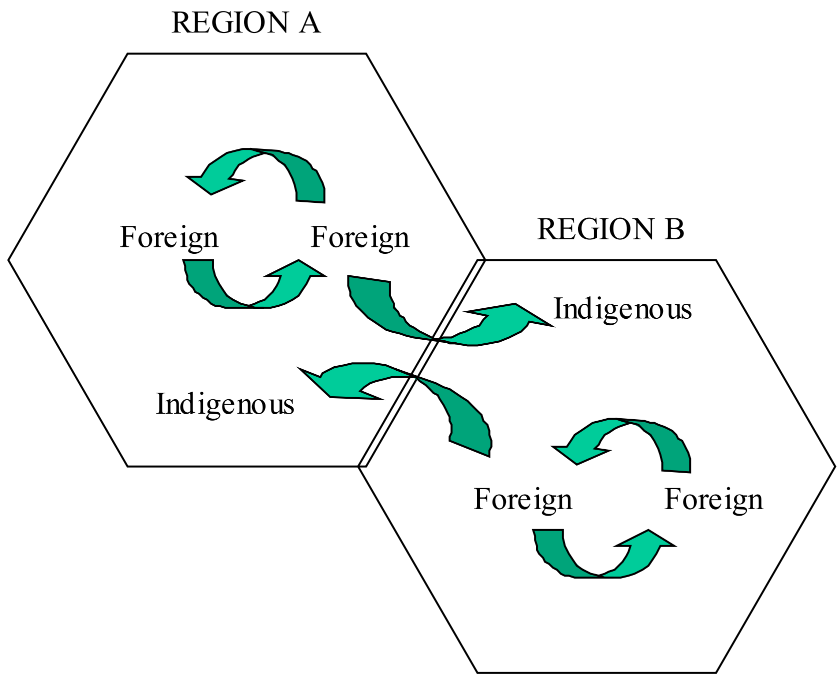


Table 1 The regional origin of foreign firm patent citing patents 1975-1995.

REGION	Cited patents*	%	Citing patents**	%
Baden Württemberg	21,351	31.8	4,828	31.1
Bayern	9,058	13.5	2,158	13.9
Hessen	9,843	14.7	2,158	13.9
Niedersachsen	3,371	5.0	792	5.1
Nordrhein-Westfalen	14,064	20.9	2,965	19.1
Rheinland-Pfalz	3,594	5.4	745	4.8
Others	5,861	8.7	1,878	12.1
Total	*67,142*	*100.0*	*15,523*	*100.0*

Note: *1975-95; ** 1969-95

Table 2 Knowledge sources for foreign firms located in Germany, 1975 – 1995.

KNOWLEDGE SOURCE	Citation frequency	% of total
Home country of the parent firm	19,391	28.9
Another foreign country	34,687	51.7
Germany	12,580	18.7
of which:		
Baden Württemberg	2,698	4.0
Nordrhein Westfalen	2,363	3.5
Bavaria	2,103	3.1
Hessen	1,277	1.9
No location code	484	0.7
*Total**	*67,142*	*100.0*

*Note: This represents the total citations that emanate the 16 German regions.

Table 3 Knowledge sources for foreign firms (by patent assignee)

	Cites to home country of parent firm		Cites to other foreign countries		Cites to local knowledge	
ASSIGNOR:	Frequency	% of total	Frequency	% of total	Frequency	% of total
(i) is the same for citing and cited patent	3078	29.0	785	4.2	4380	42.0
(ii) is another large firm in the same industry	2459	23.2	8368	44.5	1788	17.1
(iii) is another large firm in a different industry	5073	47.8	9625	51.2	1831	17.5
(iv) to another (smaller) firm	2	0.0	2	0.0	1648	15.8
(v) Other	0	0.0	5	0.0	788	7.6
Total sample	10612	100.0	*18785*	*100.0*	10435	100.0
Missing observations	8779		15902		2145	
Total Cites	*19391*		*34687*		*12580*	

Table 4 Ratio of Citations to Patents, by region.

REGION	Total citations 1975-95*	% of Total	Total patents 1969-95**	% of Total	Ratio (cit/pat)
Baden Württemberg	2698	26.3	17215	18.7	1.4
Bayern	2103	20.5	20943	22.8	0.9
Hessen	1277	12.4	11968	13.0	1.0
Niedersachsen	493	4.8	3360	3.7	1.3
Nordrhein-Westfalen	2363	23.0	24810	27.0	0.9
Rheinland-Pfalz	508	5.0	7779	8.5	0.6
Others	816	8.0	5984	6.5	1.2
Total	*10,258*	*100.0*	*92,058*	*100.0*	1.0

Note:* This column details total patents granted to the research facilities of large firms based in Germany 1969-95. ** A total of 12,580 citations are made to local invention. Of this, location codes for 2,322 citations are missing from the sample.

Table 5 Percentage of citations to regional versus outside knowledge.

	REGIONAL LOCATION OF 'CITED' PATENTS							
REGIONAL LOCATION OF 'CITING' PATENTS	Baden Württemberg	Bayern	Hessen	Nieder-sachsen	Nordrhein-Westfalen	Rheinland-Pfalz	Total (%)	Abs. no. of citations to local knowledge*
Baden Württemberg	**53.1**	17.5	7.8	2.4	15.1	4.1	*100*	2896
Bayern	16.4	**59.4**	6.8	1.5	12.7	3.3	*100*	1416
Hessen	20.5	13.5	**41.5**	3.3	14.2	7.0	*100*	1512
Niedersachsen	24.5	10.3	8.4	**41.7**	11.6	3.4	*100*	549
Nordrhein-Westfalen	11.2	13.1	6.5	3.0	**62.0**	4.2	*100*	2098
Rheinland-Pfalz	24.2	12.4	20.0	6.7	16.2	**20.5**	*100*	524
(Others)	27.2	34.4	9.4	5.8	18.5	4.7	*100*	447

*Note: Since we are interested in investigating the degree to which knowledge sourcing might be considered regionally bound, these figures correspond to the 9442 citations that reference the knowledge bases of the 6 core regions.

Table 6 Percentage of citations to regional versus outside knowledge (no self cites).

	REGIONAL LOCATION OF 'CITED' PATENTS							
REGIONAL LOCATION OF 'CITING' PATENTS	Baden Württemberg	Bayern	Hessen	Nieder-sachsen	Nordrhein-Westfalen	Rheinland-Pfalz	Total (%)	Abs. No. of self citations (% of total citations to local knowledge)
Baden Württemberg	**34.8**	17.0	14.3	4.9	24.3	4.6	*100.0*	1332 (46)
Bayern	28.2	**26.9**	15.4	3.9	22.2	3.4	*100.0*	560 (40)
Hessen	32.9	13.8	**20.3**	7.3	18.5	7.1	*100.0*	666 (44)
Niedersachsen	43.3	10.4	18.6	**6.7**	18.0	3.1	*100.0*	264 (48)
Nordrhein-Westfalen	23.5	14.5	12.1	7.0	**38.6**	4.3	*100.0*	866 (41)
Rheinland-Pfalz	31.5	9.7	28.9	8.6	19.0	**2.3**	*100.0*	302 (58)
(Others)	0.0	0.0	0.0	0.0	0.0	0.0	*0.0*	0

Table 7 Citations Revealed Technological Advantage

TECHNOLOGY	Baden Württemberg		Bayern		Hessen		Niedersachsen		Nordrhein-Westfalen		Rheinland Pfalz		MACRO GROUP
	Sourcing from within the region	Sourcing from outside the region	Sourcing from within the region	Sourcing from outside the region	Sourcing from within the region	Sourcing from outside the region	Sourcing from within the region	Sourcing from outside the region	Sourcing from within the region	Sourcing from outside the region	Sourcing from within the region	Sourcing from outside the region	
2	0.0	0.0	0.0	0.8	0.8	2.2	0.0	0.0	5.6	0.4	0.0	6.0	CHEMICAL
3	0.1	0.4	0.0	0.3	0.8	2.6	3.7	0.9	2.3	1.1	3.4	4.8	
4	2.6	0.0	0.0	0.0	0.6	0.6	17.5	1.5	0.0	7.1	0.0	2.0	
5	0.5	0.4	0.7	1.3	0.5	1.0	0.3	0.3	1.7	1.0	0.0	0.9	
6	0.7	0.1	0.0	0.8	8.8	2.9	0.0	0.0	0.3	1.2	0.0	3.9	
7	0.4	0.3	0.3	0.6	2.6	0.4	1.9	0.2	1.1	1.2	1.2	0.3	
8	0.0	0.0	0.0	0.0	0.0	3.3	0.0	0.0	0.0	0.0	0.0	0.0	
9	0.5	0.6	0.9	0.5	1.3	1.8	0.1	0.4	0.8	2.5	0.5	2.4	
10	4.0	0.4	1.1	0.4	0.4	3.9	0.0	0.0	0.2	3.2	2.1	2.3	
11	1.2	0.4	5.7	0.5	1.0	2.0	5.1	0.3	0.3	2.1	0.2	3.1	
12	2.2	1.1	1.1	0.8	0.2	1.5	11.7	0.7	0.5	2.4	0.0	1.8	
51	0.0	0.2	1.7	0.2	0.4	0.7	1.0	0.0	0.9	0.0	0.0	2.9	
55	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.3	0.0	0.0	0.0	
1	0.7	0.4	0.0	0.8	0.2	0.7	0.0	1.1	0.1	0.3	0.0	0.0	MECHANICAL
13	0.7	0.3	0.5	0.9	0.9	0.3	0.0	0.7	0.4	1.2	0.0	0.4	
14	0.3	0.7	0.2	0.7	1.9	1.5	0.2	0.9	1.7	1.0	3.2	0.8	
15	0.2	0.9	0.0	0.5	3.7	1.0	0.0	11.2	0.5	0.9	0.0	3.3	
16	0.9	0.6	0.2	0.9	0.2	0.9	0.0	1.5	1.4	1.6	0.0	0.9	
17	0.7	1.4	4.9	0.9	0.8	0.5	0.0	0.8	0.9	1.4	0.0	0.3	
18	3.9	0.7	0.1	1.1	0.0	0.3	0.0	1.0	0.1	0.7	0.0	0.4	
19	0.0	0.0	1.0	0.0	0.0	0.4	0.0	2.0	2.7	0.5	0.0	0.7	
20	1.2	1.0	0.1	1.0	0.2	0.3	1.7	1.2	3.2	0.8	0.0	0.4	
21	0.2	1.4	0.0	0.6	0.8	1.5	0.0	0.0	2.0	0.4	0.0	0.0	
22	0.0	0.0	0.0	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
23	0.0	0.2	0.3	0.0	0.0	0.0	3.7	1.1	1.1	0.3	0.0	0.0	
24	1.0	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
25	1.9	1.1	0.3	1.6	0.9	0.8	0.0	0.5	4.1	0.7	0.4	1.9	
26	0.7	0.0	0.0	0.3	3.9	0.0	0.0	1.3	0.1	0.2	0.0	0.0	
27	0.8	0.0	0.0	0.0	2.0	2.0	0.0	0.0	0.0	3.6	0.0	6.4	
28	1.4	0.5	0.3	0.5	1.4	0.6	0.5	0.9	1.0	2.2	2.6	0.4	
29	0.8	2.7	1.2	0.7	1.8	1.8	2.7	1.6	0.8	0.7	5.1	1.5	
31	1.2	3.4	0.0	0.1	2.5	2.9	0.0	0.0	0.0	0.1	2.7	2.1	
50	0.5	0.5	0.9	0.7	0.2	0.7	0.1	0.9	3.0	0.8	0.2	1.2	
53	1.4	1.0	0.4	1.8	0.2	0.8	0.4	0.6	0.6	0.5	0.3	0.5	
30	0.3	0.9	0.7	3.5	0.0	0.6	0.0	3.2	0.5	0.4	0.0	0.5	ELECTRONIC
33	0.9	0.7	1.8	0.8	0.1	0.1	0.0	1.9	0.1	0.3	0.0	0.3	
34	0.7	0.3	0.2	0.6	0.1	0.0	0.0	0.3	0.0	0.1	0.0	0.4	
35	1.2	1.9	10.2	2.1	0.0	0.0	0.0	0.0	0.5	0.1	0.0	0.0	
36	1.4	1.2	0.4	0.8	1.3	1.5	1.5	3.0	0.0	0.1	0.0	0.0	
37	0.9	0.6	0.1	1.7	0.3	0.1	0.0	0.9	2.2	0.9	0.0	0.0	
38	0.7	0.7	0.9	1.3	0.4	0.4	0.1	0.8	0.3	0.5	0.3	0.1	
39	1.4	1.1	0.2	0.9	0.6	0.7	0.0	0.1	0.8	0.6	0.2	0.6	
40	1.5	0.6	0.6	1.5	0.3	0.2	0.0	0.3	0.1	0.0	0.0	0.2	
41	1.1	0.4	0.3	0.8	1.1	0.8	0.9	1.5	0.1	0.1	0.0	0.2	
52	1.0	0.2	0.0	2.2	1.2	0.4	0.0	2.9	0.0	0.2	0.0	0.0	

Table 7 continued ..

TECHNOLOGY	Baden Württemberg		Bayern		Hessen		Niedersachsen		Nordrhein-Westfalen		Rheinland Pfalz		MACRO GROUP
	Sourcing from within the region	Sourcing from outside the region	Sourcing from within the region	Sourcing from outside the region	Sourcing from within the region	Sourcing from outside the region	Sourcing from within the region	Sourcing from outside the region	Sourcing from within the region	Sourcing from outside the region	Sourcing from within the region	Sourcing from outside the region	
42	0.6	5.2	1.0	0.8	0.7	0.0	0.0	0.0	0.2	0.4	0.0	0.5	TRANSPORT
43	0.4	2.8	0.7	4.7	6.0	1.6	0.4	1.8	1.7	0.7	1.8	1.7	
44	0.7	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
45	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	
46	0.7	0.9	0.6	1.6	0.0	0.8	0.0	0.0	2.4	1.4	0.0	0.0	
47	2.8	0.0	0.3	1.2	0.4	1.2	0.0	1.7	0.4	0.9	0.0	0.8	
49	0.1	0.4	0.2	0.8	0.9	0.5	0.0	4.3	0.9	1.7	0.6	2.0	
32	3.2	0.0	0.0	2.2	0.3	2.3	0.0	0.4	0.2	6.9	3.0	2.4	
48	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	OTHER
54	2.6	3.5	0.0	2.3	1.8	0.0	0.0	10.9	0.0	1.6	0.0	1.4	
56	0.2	0.5	0.0	1.4	0.9	0.0	0.0	0.0	0.7	0.9	1.8	0.0	
Total	*1.0*	*1.0*	*1.0*	*1.0*	*1.0*	*1.0*	*1.0*	*1.0*	*1.0*	*1.0*	*1.0*	*1.0*	
Pearson Correlation	0.083		0.077		.339*		-0.014		-0.138		0.217		

Table 8 Results from regression analysis (Citations RTA with self cites)

REGION		Insiders RTA* Std. Coefficients	t-statistic	Signif.	Adjusted R2	Outsiders RTA* Std. Coefficients	t-statistic	Signif.	Adjusted R2
	RTAg	-0.106	0.128	0.899	0.187	0.662	6.343	**0.000**	0.041
Baden Württemberg	RTAf	0.463	3.774	**0.000**		-0.109	-1.045	0.301	
	RTAg	0.308	-1.655	-104	0.153	0.003	0.023	0.982	-0.350
Bayern	RTAf	0.242	3.392	**0.001**		-0.051	-0.357	0.723	
	RTAg	0.115	0.981	0.331	0.269	0.349	2.702	**0.009**	0.107
Hessen	RTAf	0.514	4.407	**0.000**		0.089	0.689	0.494	
	RTAg	-0.252	-1.863	0.068	0.215	0.072	0.467	0.642	-0.030
Niedersachsen	RTAf	0.557	4.125	**0.000**		-0.091	-0.589	0.559	
	RTAg	-0.106	-0.783	0.437	0.025	0.528	4.441	**0.000**	0.244
Nordrhein-Westfalen	RTAf	0.24	1.781	0.081		-0.089	-0.746	0.459	
	RTAg	0.083	0.909	0.367	0.575	0.266	2.01	**0.049**	0.041
Rheinland-Pfalz	RTAf	0.738	8.07	**0.000**		0.064	0.483	0.631	

Table 9 Results from regression analysis (Citations RTA omitting self cites)

REGION		Insiders RTA* Std. Coefficients	t-statistic	Signif.	Adjusted R2	Outsiders RTA* Std. Coefficients	t-statistic	Signif.	Adjusted R2
Baden Württemberg	RTAg	0.158	1.309	0.196	0.214	0.791	9.202	**0.000**	0.601
	RTAf	0.446	3.699	**0.001**		-0.070	-0.810	0.421	
Bayern	RTAg	-0.099	-0.963	0.340	0.469	-0.008	-0.055	0.956	-0.033
	RTAf	0.724	7.002	**0.000**		-0.065	-0.451	0.654	
Hessen	RTAg	0.192	1.627	0.11	0.255	0.54	4.595	**0.000**	0.258
	RTAf	0.467	3.961	**0.000**		-0.074	-0.633	0.529	
Niedersachsen	RTAg	-0.163	-1.111	0.272	0.076	0.074	0.480	0.633	-0.027
	RTAf	0.373	2.547	**0.014**		-0.115	-0.744	0.46	
Nordrhein-Westfalen	RTAg	-0.54	2.153	0.036	-0.034	0.575	5.020	**0.008**	0.299
	RTAf	-0.016	-0.114	0.910		-0.152	-1.324	0.191	
Rheinland-Pfalz	RTAg	0.028	0.203	0.840	-0.024	0.359	2.800	**0.007**	0.097
	RTAf	0.111	0.812	0.420		0.022	0.171	0.865	

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