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Combining knowledge from different sources, channels and geographical scales

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ABSTRACT

The aim of this article is to examine conceptually and empirically how innovative firms combine knowledge (1) provided by different sources, (2) accessed at different spatial scales, and (3) acquired through different channels. We add to the conceptual debate by contrasting and synthesizing the perspectives offered on these issues by four key concepts, namely the local buzz and global pipelines argument, the knowledge base approach, the notions of STI and DUI modes of innovation as well as the regional innovation systems concept. The empirical part of the article contains an analysis of knowledge sourcing activities and knowledge combinations employed by 181 firms belonging to the Austrian automotive supplier industry. Our findings reveal that it is, indeed, combinations of knowledge sourced from different partners located at different spatial scales and acquired through different channels that are relevant. However, it is particular knowledge combinations that dominate while others are negligible. Austrian automotive supplier firms combine knowledge provided by customers with knowledge inputs from a variety of other sources. Most of the combinations involve the international level combined with the regional and/or national level. Finally, firms combine spillovers with a variety of other channels to acquire innovation-relevant knowledge.

JEL Code: O30, R10, D83

Keywords: Innovation, Knowledge Bases, Regional Innovation System, Geography, Automotive

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Abstract

The aim of this article is to examine conceptually and empirically how innovative firms combine knowledge (1) provided by different sources, (2) accessed at different spatial scales, and (3) acquired through different channels. We add to the conceptual debate by contrasting and synthesizing the perspectives offered on these issues by four key concepts, namely the local buzz and global pipelines argument, the knowledge base approach, the notions of STI and DUI modes of innovation as well as the regional innovation systems concept. The empirical part of the article contains an analysis of knowledge sourcing activities and knowledge combinations employed by 181 firms belonging to the Austrian automotive supplier industry. Our findings reveal that it is, indeed, combinations of knowledge sourced from different partners located at different spatial scales and acquired through different channels that are relevant. However, it is particular knowledge combinations that dominate while others are negligible. Austrian automotive supplier firms combine knowledge provided by customers with knowledge inputs from a variety of other sources. Most of the combinations involve the international level combined with the regional and/or national level. Finally, firms combine spillovers with a variety of other channels to acquire innovation-relevant knowledge.

Keywords:

- Innovation
- Knowledge Bases
- Regional Innovation System
- Geography
- Automotive

INTRODUCTION

Processes of innovation have undergone a significant transformation over the past years, becoming increasingly complex, interactive and open in nature (Chesbrough, 2003; Kline & Rosenberg, 1986; Lundvall, 1988). Innovation-relevant knowledge is more and more distributed across different actors (Asheim, Boschma, & Cooke, 2011; Howells, 2012; Strambach & Klement, 2012), forcing companies to rely on knowledge generated outside their boundaries and fuelling a rise in importance of external knowledge sourcing activities.

Three dimensions of knowledge sourcing activities have been of central interest and an enduring theme over the past years. These include (1) the sources of knowledge (i.e., the main innovation partners), (2) the geography of knowledge sourcing activities, and, (3) the channels by which knowledge is acquired. The literature on these dimensions is abundant and has essentially enhanced our understanding of the significance of knowledge sourcing activities for innovation. However, it also claims that certain knowledge sources and innovation partners, geographical levels and channels are more relevant than others. In contrast to such propositions, more recent conceptual and empirical research suggests that it is the combination of knowledge from different sources, geographical scales and channels that is conducive to innovation (see, for instance, Asheim, et al., 2011; Strambach & Klement, 2012). What remains, however, fiercely debated in the literature is which particular combinations matter during the innovation process.

The aim of this paper is to advance our understanding of how innovative firms combine knowledge (1) from different sources, (2) accessed at different spatial scales, and (3) acquired through different channels. Our contribution is twofold. First, we add to the conceptual debate by contrasting and synthesizing the perspectives offered by four popular approaches on knowledge sourcing activities, namely the local buzz and global pipelines argument, the knowledge base approach, the STI and DUI modes of innovation as well as the regional innovation systems (RIS) concept. Second, looking at the automotive supplier industry in three Austrian regions, we provide empirical insights into combinations of knowledge sourcing activities. This article thus addresses the following research questions:

- How are combinations of knowledge sourcing activities embraced by main theoretical approaches in the field and how do these approaches differ in their conceptualization of such practices?

- How do innovative firms in the Austrian automotive supplier industry combine knowledge from different sources, geographical scales and channels?

The remainder of this article is organized as follows. Section 2 establishes the theoretical framework and engages in a review and critical discussion of several conceptual approaches that deal with the relation between knowledge sourcing and innovation. We uncover similarities and differences in their views on combinations of knowledge sourcing activities. Section 3 contains the empirical part of the paper. We provide an overview on some key features of the Austrian automotive supplier industry and its three main regional centres; discuss the methods applied in our empirical investigation and present important sample characteristics. This is followed by an analysis of how Austrian automotive suppliers combine knowledge from different sources, channels and spatial scales. Finally, Section 4 concludes and elaborates on the policy implications of our findings.

CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

In the recent past, knowledge sourcing activities have attracted considerable attention from economic geographers and academics working in the field of innovation. In this section we compare different conceptual approaches that have added to theorizing about the nature and geography of knowledge sourcing activities. We will highlight what they have to offer regarding (i) the three dimensions (sources, geography, and channels) of knowledge sourcing activities and (ii) their combinations.

Over the past 20 years, various territorial innovation models (for an overview, see Moulaert & Seika, 2003) have stressed the importance of regional knowledge sourcing activities for innovation. Meanwhile there is a growing recognition that linkages to distant knowledge sources are also critically important. Many scholars agree that regional and international knowledge connections complement each other and that it is combinations of knowledge acquired at various spatial scales that underpins innovation (Simmie, 2005; Wolfe & Gertler, 2004). The notion of "local buzz and global pipelines", championed by Bathelt et al. (2004), performs prominently in current discussions about the interrelatedness of local/regional and global knowledge linkages. Whilst local buzz refers to free and automatic participation in (often unintended) knowledge circulation resulting from co-location, global pipelines are seen as deliberately established connections to distant knowledge sources, providing access to external knowledge pools, new technologies and markets. Accessing knowledge through

global pipelines rests on planned efforts of firms to access specific knowledge and is more risky and costly when compared to buzz. Bathelt et al. (2004) claim that the forms and quality of buzz as well as the extent to which firms access global knowledge through pipelines have important effects on innovation in clusters. Also, they argue that being located in a cluster tends to facilitate the creation of local buzz and global pipelines. The buzz and pipelines approach has been criticized for a variety of reasons. A key shortcoming of this approach is that it conflates buzz with personal interaction and pays little attention to the absorptive capacity of actors as precondition for using the content of buzz (Dahlström & James, 2012; Moodysson, 2008). Another limitation of the buzz and pipelines argument is its failure to specify in more detail the channels by which actors in a cluster get access to knowledge at different spatial scales (Trippl, Tödtling, & Lengauer, 2009). Finally, several empirical studies (see, for instance, Moodysson, 2008; Tödtling, Grillitsch, & Höglinger, 2012; Trippl, et al., 2009) have demonstrated that innovation is based on a more complex pattern of knowledge links than suggested by the buzz and pipelines argument.

In contrast to the local buzz and global pipelines argument, the knowledge base concept offers a more differentiated view on knowledge sourcing patterns. The concept explains all three dimensions of knowledge sourcing activities through the knowledge bases that prevail in firms or industries (Asheim & Gertler, 2005; Martin & Moodysson, 2013). The concept distinguishes between three types of knowledge bases: (i) analytical, (ii) synthetic and (iii) symbolic. An analytical knowledge base dominates in industries where scientific knowledge is relevant, and where knowledge production rests on formal models, codified science and rational processes. Knowledge sourcing activities are dominated by collaborations with universities and other research organizations and tend to occur on a global scale. A synthetic knowledge base typically represents engineering-focussed firms where tacit knowledge plays a more important role. The dominant knowledge sources are clients and suppliers and it is assumed that geographic proximity is more relevant than for firms with an analytical knowledge base. Finally, a symbolic knowledge base is present in cultural industries in which innovation is about the creation of meaning, desire and aesthetic values. Symbolic knowledge is highly tacit and context specific. Accordingly, knowledge interactions are assumed to be mainly localized, taking place within project teams. Thus, knowledge sourcing patterns and the characteristics of the three dimensions considered in this paper (sources, geography, and channels) are viewed as industry-specific phenomena, depending on the underlying knowledge base. Empirical evidence (see, for instance, Manniche, 2012; Martin, 2013; Martin & Moodysson, 2013) appears to provide support for these claims. Recently, attempts have

been made to elaborate on the importance of connecting differentiated knowledge bases by linking the concept to the notion of related variety (Asheim, et al., 2011). The concept of related variety advances the idea that neither specialisation nor diversification per se stimulates innovation but the existence and linkages between sectors and firms with related knowledge bases. Evidence was found that co-location of firms from related industries is more conducive to innovation than co-location of firms from the same sector or from unrelated ones (Frenken, van Oort, & Thijs, 2007). Accordingly, Asheim et al. (2011, p. 899) argue that it is important to understand "how different knowledge bases are combined and intertwined in a dynamic manner between firms and industries of related variety".

Also, Jensen et al. (2007) draw attention to the combination of different forms of knowledge and modes of innovation. The authors promote the idea that firms combining different modes of innovation are more innovative than those that rely on one mode only (see also Isaksen & Karlsen, 2011; Trippl, 2011). The authors differentiate between the Science-Technology-Innovation (STI) and the Doing-Using-Interacting (DUI) mode of innovation. As regards forms of knowledge, they relate to the distinctions between local and global knowledge as well as various types of knowledge, namely explicit knowledge (know-what, know-why) and implicit knowledge (know-how, know-who). Jensen et al. (2007) put forward the argument that all forms of knowledge matter for both modes of innovation. However, the relative importance differs between the STI and DUI mode of innovation. The STI mode of innovation relies to a larger extent on explicit and global knowledge, with a particular emphasis on know-why and know-what. In contrast, the DUI mode of innovation depends more on implicit and local knowledge where know-how and know-who play a more important role. Jensen et al. (2007, p. 685) provide empirical evidence that "it is the firm that combines a strong version of the STI-mode with a strong version of the DUI-mode that excels in product innovation".

The RIS approach (Asheim & Gertler, 2005; Cooke, 2001) differs in some respects markedly from the work on knowledge bases and STI/DUI modes of learning. Patterns of knowledge sourcing are not explained by the underlying knowledge bases and innovation modes of industries but by the specificities of the organizational and institutional setting prevailing at the regional level, i.e. by RIS characteristics. Innovation is considered as the outcome of interactive learning within and between two subsystems. The RIS subsystem of knowledge generation contains universities and other research organizations, educational bodies and technology transfer agencies. The RIS subsystem of knowledge application is made up of the

firms located in a region, which turn knowledge into valuable products. The RIS concept emphasizes that knowledge sourcing activities at the regional level are pivotal, because the exchange of (particularly tacit) knowledge is facilitated by geographical proximity and region-specific shared cultural and institutional contexts. However, at the same time, proponents of the RIS concept acknowledge that also external knowledge links are important. Recent work has demonstrated that firms located in institutionally thin RIS are more engaged in extra-regional knowledge sourcing activities than firms embedded in institutionally thick RIS (Chaminade, 2011; Tödtling, et al., 2012).

Table 1 summarizes the views suggested by the four concepts on (1) knowledge sources, (2) the geography of knowledge flows, and (3) channels of knowledge transmission. As illustrated in Table 1 and discussed above, there is little consensus among the main protagonists of the four approaches as regards the nature of these three dimensions of knowledge sourcing activities and their determinants.

Insert Table 1 approximately here

The four concepts discussed above offer partly similar and partly different perspectives on the patterns of knowledge sourcing and their relation to innovation. The concepts vary in the extent to which they address the three dimensions of knowledge sourcing. In contrast to the other three approaches considered in this paper, the buzz and pipelines argument focuses only on two dimensions (geography and channels) while the knowledge sources remain unspecified. Both the knowledge base approach and the literature on STI/DUI learning modes identify in a rather clear way critical knowledge sources and demonstrate conceptually how they differ between industries. The RIS views both firms and scientific knowledge providers as potentially important knowledge sources within RIS. The relative importance of these sources is assumed to vary, depending on RIS configurations. All four approaches offer perspectives on the geography of knowledge sourcing activities. The buzz and pipelines approach suggests that both local and global knowledge is equally important for innovation, stressing the complementary relation of both spatial scales. Similar arguments can be found in the STI/DUI literature. This view is challenged by the knowledge base concept, which highlights that the significance of local and global (and national) spaces differs depending on

industries and their underlying knowledge bases. The RIS approach clearly emphasizes the importance of the regional arena for knowledge sourcing. However, it is also taken into account that specific institutional configurations (particularly thin RIS structures) favour a high extent of extra-regional knowledge sourcing practices. All four concepts reviewed in this paper remain rather vague when it comes to identifying key knowledge transfer channels. The buzz and pipelines approach draws a crude distinction between informal and formal channels but fails to capture the variety of channels relevant for knowledge sourcing. The same holds true for the work that has been done by scholars investigating STI and DUI modes of learning. The RIS approach underlines the importance of interactive learning (i.e. networks) at the regional level but has little to say about the precise nature of extra-regional knowledge linkages. The knowledge base approach identifies a few channels (such as formal R&D collaborations, network relationships between users and producers, short-term temporary networks and project groups), which are assumed to differ in importance between analytical, synthetic and symbolic industries. Finally, and most important given the purpose of this paper, we find dissimilarities between the four concepts with respect to their assessment of knowledge combinations. The importance of such combinations is most emphasized by the buzz and pipelines argument (combination of regional informal knowledge and global formal knowledge sourcing activities) and the STI/DUI approach (combination of knowledge links that reflect different learning modes). The knowledge base concept and the RIS approach, in contrast, are more focused on identifying and explaining why certain sources, spatial scales and channels are dominating. The literature on knowledge bases and RIS has only recently begun to draw attention on combinations of these practices (see, for instance, Asheim, et al., 2011; Strambach & Klement, 2012).

To sum up, the reviewed concepts offer different perspectives on combinations of knowledge acquired from different sources, accessed at various spatial scales and transmitted through different channels. While the importance of combinations of knowledge is increasingly recognised, it remains obscure, which specific combinations are conducive to innovation.

EMPIRICAL ANALYSIS OF KNOWLEDGE COMBINATIONS OF AUSTRIAN AUTOMOTIVE SUPPLIERS

SETTING THE SCENE: KEY CHARACTERISTICS OF THE AUTOMOTIVE INDUSTRY

The automotive industry is an interesting sector for investigating combinations of knowledge sources. In this sector, we find global value chains with original equipment manufacturers (OEMs) on the top of the hierarchy. OEMs rely largely on tier 1 suppliers that produce module or system solutions and take on R&D roles (Bailey, de Ruyter, Michie, & Tyler, 2010; Dicken, 2011). Outsourcing of production and innovation activities by OEMs to suppliers is a prevalent feature of the car industry. Tier 1 suppliers coordinate activities with suppliers further down in the hierarchy. This implies that innovations need to be compliant and add value in the context of the products, modules or systems produced by the supplier's client may it be an OEM or a higher tier supplier. Therefore, one can expect extensive knowledge links amongst organisations of the value chain both vertically (clients and suppliers) as well as horizontally (competitors). At the same time, it has been observed that automotive firms collaborate frequently with scientific knowledge providers (universities and R&D institutes) as well as engineering and consulting firms. Given the large variety of knowledge sources and modes of knowledge acquisition, it is intriguing to examine how firms combine them during the innovation process. Furthermore, automotive firms tend to cluster in space. Accordingly, the empirical study shall give us evidence for a variety of regional knowledge links. On the other hand, the sector's value chain is characterised by a high degree of internationalisation and hence, one can expect to also observe vivid international knowledge sourcing activities (Sturgeon, Van Biesebroeck, & Gereffi, 2008). Furthermore, the automotive sector is classified as medium-high technology industry (OECD, 2011) and, as a typical engineering-intense sector generally associated with a synthetic knowledge base (Asheim, et al., 2011). Industries with a synthetic knowledge base predominantly apply a DUI mode of innovation and tend to generate more incremental innovations.

THE AUSTRIAN CASE

The automotive industry is a key sector of the Austrian economy. According to the Austrian industry association (Fachverband Fahrzeugindustrie Österreich - FFÖ, 2012), it belongs to the nation's four most important manufacturing sectors and ranks second behind the machine building industry as regards exports. The Austrian automotive industry concentrates in four neighbouring political-administrative regions: Upper Austria, Lower Austria, Vienna and

Styria. Our empirical study comprises all four areas. Vienna is located in the very centre of Lower Austria. The two regions have joint cluster support organisations and are listed as one region by the Austrian Automotive Association. Therefore, in this paper Vienna and Lower Austria are viewed as one region. All three Austrian automotive regions are characterised by relatively strong and institutionally thick RIS structures. They host a rather large number of automotive suppliers and are well endowed with research organisations and educational bodies with competencies in the automotive field as well as policy and supporting organisations that promote innovation and knowledge exchange in this sector.

Vienna region (including Lower Austria) hosts around 130 automotive suppliers. This region differs from Upper Austria and Styria as regards the prevailing industrial structure. Being Austria's capital and largest agglomeration, Vienna is characterised by more diversified economic activities than Upper Austria and Styria. In contrast, the later have a long industrial tradition. Accordingly, the firms in Vienna region are particularly known for their competence in cross-cutting technologies. In Upper Austria one finds a large variety of suppliers for the automotive industry, manufacturers of equipment and machinery as well as leading firms in market niches such fire fighting vehicles (Rosenbauer) or motorcycles (KTM). Upper Austria is home of around 150 automotive supplier companies. In contrast, Styria's automotive supplier industry (110 firms) is dominated by MAGNA, one of the world's leading automotive suppliers, with approximately ten thousand employees located in Styria. Styria has strengths in assembling complete cars, four-wheel drives, and materials (Höglinger, 2012).

As regards the knowledge exploration subsystem, all three regions are well endowed with universities and R&D institutes. Overall, Vienna region offers the largest variety of scientific knowledge providers, reflecting its status as Austria's capital and scientific centre. Among the most relevant organisations for the automotive industry are the Technical University Vienna, the Austrian Institute of Technology and the Centre for Virtual Reality and Visualisation. Although relevant knowledge providers are located in both Styria and Upper Austria, the knowledge exploration system in Styria has advantages as compared to the one in Upper Austria, both in quantity as well as quality of relevant organisations. The main players in Styria's knowledge exploration system are the Technical University Graz, Montan Universität Leoben, Joanneum Research as well as a large number of competence centres. In Upper Austria, Johannes Kepler University Linz and Linz Centre of Mechatronics conduct relevant research and educational activities.

In all three regions, the automotive industry receives strong political support, which is mainly implemented through cluster policies. The first cluster initiative dedicated to the automotive field was launched in Styria in the mid-1990s (Trippl & Otto, 2009). Some years later, similar policy strategies have been implemented in Upper Austria and Vienna. Cluster policy actions are directed towards enhancing the innovation capacities and competitiveness of firms active in fields related to the automotive value chain, strengthening formal and informal networking on the regional, national and international levels as well as marketing and promotion of the regions as attractive locations for the automotive sector.

The three investigated Austrian regions benefit from geographic proximity to major European automotive regions. Germany is the most important export market for the Austrian automotive industry. In Germany, the automotive industry is concentrated in the southern provinces of Baden-Württemberg and Bavaria, the latter borders with Upper Austria. Also, eastern neighbouring countries of Austria have gained importance for the automotive industry, namely the Czech Republic, Slovakia, Hungary and Slovenia. Upper Austria benefits from its close proximity to the Czech Republic. Styria is particularly close to Hungary and Slovenia. Slovakia, the Czech Republic and Hungary are also easily accessible from Vienna. In these countries, some German OEMs and clients of the Austrian automotive firms have opened production sites such as Audi in Bratislava (Slovakia) and Györ (Hungary) or Mercedes in Hungary. In consequence, Austrian automotive firms have increased their engagement in the Eastern neighbouring countries to better serve existing clients and gain new ones.

In summary, Vienna and Lower Austria, Upper Austria and Styria have rather strong RIS. Being embedded in well-functioning, institutionally thick RIS, firms in all three regions have opportunities to source knowledge regionally. Regional knowledge dynamics are supported by policy through measures targeting formal and informal networking and knowledge exchange. Equally, the investigated automotive firms in all three regions are located in proximity to important foreign automotive clusters in Germany, the Czech Republic, Slovakia, Hungary and Slovenia. The firms' export ratio is high and, therefore, the accessibility to these clusters plays an important role. Overall, therefore, we expect that regional and international knowledge sourcing activities play an important role for firms regardless their location in Vienna and Lower Austria, Upper Austria or Styria.

DESCRIPTION OF THE SAMPLE AND INVESTIGATED FIRMS

The data draws from a survey, conducted between March and October 2007, which includes suppliers and producers of machinery for the automotive sector. It excludes Original Equipment Manufacturers (OEMs) because of i) the low number of OEMs in Austria and ii) the differences in the production and innovation processes between OEMs and typical suppliers and producers of machinery. All firms listed in "Top of Austria 2006", which is the complete registry of automotive suppliers in Austria, were contacted and invited to participate in our study. The total population counted 387 firms in Upper Austria, Lower Austria, Vienna and Styria. The survey resulted in 181 responses (47% response rate) as shown in Table 2.

Insert Table 2 approximately here

Table 3 presents important characteristics of the surveyed firms. Of the 181 firms in the sample more than 90% perform production activities. The majority of firms produce in small batches (61%) followed by such active in large batch production (54%). Job production is also relatively common with 40% while mass production is the least frequent mode of production. As regards innovation activities, many firms are active in product development (74%) and in process development (65%). As expected for a sector with a synthetic knowledge base where the DUI mode of innovation dominates, basic and applied research occurs less frequently. Still it is worth noticing that 25% of the firms conduct applied research and 13% basic research on a regular basis. Therefore, R&D focuses rather on development than on research, which puts the high share of firms (61%) undertaking R&D in perspective. We find that the large majority of firms are innovative as more than 80% of them reported having generated product and process innovations. As regards product innovations, approximately half of the firms introduced innovations that are new to the firm and a similar share reported having created products that are even new to the market. The more substantive processes innovations are less frequent. 42% of the firms introduced processes new to the firm and 28% processes new to the sector. Overall, these characteristics confirm the categorisation of the empirical case as medium-high tech industry where a synthetic knowledge base and the DUI mode of innovation dominate. It is important to note, however, that although we selected a consistent subgroup of the automotive industry the investigated

firms are heterogeneous. This implies that other knowledge bases and modes of innovation will blend with the dominant ones.

Table 3 presents additional firm characteristics with importance for the interpretation of the results. As common in the automotive industry, the investigated subsector is highly internationalised and characterised by relatively large-sized firms as compared to the average of the economy. Most responding firms are medium-sized (41%) followed by large-sized ones (38%). Small firms account for only 21% of the sample. According to the FFÖ (2011) 66% of the firms belonging to the Austrian automotive industry are SMEs and 31% have fewer than 50 employees. In the sample, therefore, small firms are underrepresented while medium and large firms are slightly overrepresented. More than 60% of the surveyed firms are part of a group and 23% of the firms have headquarters located internationally (14% in Europe and 9% outside Europe)[1].

Insert Table 3 approximately here

ANALYSIS OF KNOWLEDGE COMBINATIONS

In this section, we discuss the findings for knowledge combinations in three subsections: i) combinations of knowledge sources, ii) combinations of knowledge channels, and iii) geographic combinations of knowledge sources and channels[2].

Before doing so, two notes are necessary. First, the findings presented below are aggregate results for all three regions because our analysis of firms' knowledge sourcing activities for each region individually has shown that the differences between the three areas are only

[1] As regards potential non-response biases, we see a certain risk that non-innovative firms were less likely to fill in the questionaire. However, as we are mainly interested in the knowledge combinations relevant for innovation activities, this potential non-response bias has no effect on our results and findings.

[2] Firms were asked to indicate, which types of knowledge sources and channels were important or very important to them for the improvement of existing or the development and introduction of new products and processes. In a second step, the firms were asked to indicate on which geographic scales their important sources and channels were located.

minor. Second, we also assessed potential relations between certain knowledge combinations and innovation activities as well as outputs. The results were only partly conclusive and pointed to a complex relation that requires additional analyses, which are, however, beyond scope of this paper[3].

As regards knowledge sources we distinguish between clients and suppliers constituting the firms' value chain; competitors; scientific knowledge providers such as universities and R&D institutes; engineering and consulting services; and lastly firms of other sectors. To investigate channels of knowledge transfer, we use a differentiated typology introduced by Tödtling et al. (2006) and Trippl et al. (2009), which identifies four main types: market links, formal networks, informal networks and spillovers. Spillovers contain the attendance of fairs, seminars, congresses and workshops; reading of literature and patents; observation of other firms; and recruitment of skilled workers. For market links the survey includes buying licences, machines and equipment; consulting and engineering contracts; as well as research contracts. Formal networks are associated with R&D co-operations and informal networks with private contacts and participation in working groups. With respect to spatial scales, we distinguish between regional, national and international levels. Regional refers to the respective location of the firms, e.g. for firms located in Upper Austria, regional means Upper Austria. The same holds true for firms located in the region of Styria or the region of Vienna and Lower Austria.

Combinations of knowledge sources

Table 4 shows the relative importance of different types of knowledge sources. Clients are by far the most important knowledge source for Austrian automotive firms. More than 90% of the surveyed firms consider clients as important (67% even as very important). Competitors, suppliers, universities and R&D institutes are relevant for approximately half of the firms. Interestingly, only few firms rated these sources as very important. Engineering and consulting companies play a significant role as knowledge source for only a third of the firms and even fewer firms indicated that other sectors are important.

Table 5 illustrates how firms combine knowledge sources that have been assessed as important. In order to facilitate the interpretation of results, we grouped organisations that

[3] Results of these analyses are available upon request.

focus on generating scientific knowledge such as universities and R&D institutes together ("scientific knowledge providers"). Furthermore, we have excluded engineering and consulting companies as well as firms from other sectors in this analysis because relatively few firms considered them to be important[4]. As shown in Table 5, with very few exceptions, knowledge sourcing is a combination of acquiring knowledge from clients and other sources. The highest observed frequency relates to firms using all types of knowledge sources. Also, it becomes apparent that combinations of clients and providers of scientific knowledge are most common. 57% of all firms use both clients and providers of scientific knowledge as sources during the innovation process. These firms further add knowledge from competitors (15%), suppliers (13%) or both (19%). Overall, these combinations of knowledge sources reflect quite well the presumed ones for industries dominated by a synthetic knowledge base (Asheim & Gertler, 2005). Such firms are expected to develop solutions to problems and challenges faced by their clients, may it relate to improved product qualities, lower production costs or an increase in flexibility. Consequently, their innovations need to fit or be integrated with the production processes of their clients. Innovation processes, thus, usually involve a close interaction with clients. For specific technological challenges and testing, firms use the knowledge provided by universities and research organisations.

Insert Table 4 approximately here

Insert Table 5 approximately here

Combinations of knowledge channels

Table 6 shows the importance of different knowledge channels. Interestingly, various forms of spillovers (attendance of fairs, seminars, congresses and workshops, reading of literature and patents, observation of other firms, recruitment of skilled workers) rank particularly high

[4] Including those types of sources does not change the overall picture presented here.

in importance. This observation challenges recent assumptions that spillovers are inferior to networks (Boschma & Ter Wal, 2007; Giuliani, 2007; Morrison, 2008). Certain types of market links, particularly buying machines and equipment also play a central role. Around 30% of the firms assessed them as very important while other market links (consulting, engineering and research contracts) are considered by fewer firms as relevant. Buying licences even turned out to be the least important channel. As regards network links, every second firm mentioned that R&D co-operations play a significant role. Finally, looking at informal networks reveals that private contacts are relevant to more firms than the participation in working groups.

Table 7 presents how firms combine the main types of knowledge channels. Interestingly, one third of the firms combine all four types of knowledge channels. The large majority of firms (more than 90%) rely on spillovers combined with other channels. More than three forth of the firms acquire knowledge by combining spillovers and market links. R&D co-operations and informal networks are considered important by approximately the same number of firms and are combined with spillovers and market links to about the same extent. All other combinations of knowledge channels are rare.

Insert Table 6 approximately here

Insert Table 7 approximately here

Geographic combinations of knowledge sources and channels

As regards the geographic dimension, the firms were asked to indicate on which spatial level (regional, national, and international) they used important knowledge sources and channels (see Table 8). The international level seems to be of utmost significance. More than 90% of the firms use international sources. One fifth of the firms use international sources only. However, the results also clearly indicate that the majority of firms combine knowledge from various spatial levels. 40% of the investigated firms use all spatial levels. Furthermore, 21%

combine sources at the international and national levels and 9% at the international and regional level. Therefore, more than 70% of the firms combine knowledge stemming from international sources with regional and/or national sources.

As Table 9 illustrates, the international level is particularly relevant for sourcing knowledge from organisations along the value chain (clients, suppliers, competitors) while the regional and national levels have turned out to play a larger role for scientific knowledge providers (universities, R&D institutes) as well as engineering and consulting firms. This finding is somewhat surprising from the knowledge base perspective. The automotive sector is assumed to rely mainly on a synthetic knowledge base, where innovation processes often require interactions between clients and suppliers (as confirmed in our data). For such knowledge interactions, geographic proximity is assumed to be important. On the other hand, interactions with scientific knowledge providers are viewed to be less place-dependent. The results of the Austrian automotive industry clearly challenge these views and point to the need to consider not only knowledge bases but also the industry's value chain RIS conditions. The high importance of regional and national knowledge sourcing from providers of scientific knowledge reflects the excellent endowment of the RISs with universities and research organisations; the dominance of linkages to international clients and suppliers can be explained by the strong insertion of the sampled firms into global value chains.

Insert Table 8 approximately here

Insert Table 9 approximately here

Firms also indicated on which spatial level they used particular knowledge channels. In this respect, combinations play an even more important role. Two third of the firms use all geographic levels to acquire knowledge through different channels (see Table 10). In addition, 10% combine international and regional channels and 7% international and national ones. In total, 83% of the firms combine different spatial levels while 11% use the international level only. Overall, however, the international level plays with approximately 94% again the most

prominent role. Interestingly, three of the four observed spillover mechanisms (literature and patents, observation of other firms, attendance of fairs, seminars, congresses, and workshops) apply most frequently on the international level. Only recruitment of skilled workers has turned out to be a relatively local phenomenon. In line with the observation that scientific knowledge providers are used more on the regional and national level, also related channels such as R&D co-operations and research contracts are used relatively frequently on these levels. Buying machinery, equipment and licences, being typical market links with suppliers or firms from the same sector, occurs more frequently on the international level. On the other hand, informal networks (participation in working groups and particularly informal contacts) are relatively frequent but not exclusive on the regional and national levels.

Insert Table 10 approximately here

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Conclusions

This paper sought to shed light on how firms combine knowledge from different sources, spatial scales and various channels during the innovation process. Based on a review of four key theoretical approaches, we have shown that there is little consensus in the conceptual debate regarding combinations of knowledge sourcing activities. Our empirical analysis of knowledge sourcing activities in the Austrian automotive supplier industry has demonstrated that combinations of knowledge from different sources, channels and spatial scales are highly relevant. Drawing on the results of a survey of 181 automotive suppliers, we have shown that particular knowledge combinations are relevant while others are negligible.

Looking at combinations of specific knowledge channels, we found a high importance of spillovers and market links (in particular buying machines and equipment). This is interesting because recent work puts an increasing focus on networks as opposed to spillovers (Boschma & Ter Wal, 2007; Giuliani, 2007; Morrison, 2008). The results of this study, however, suggest

that spillovers remain important for knowledge circulation. Not less than 90% of the firms acquire knowledge by combining spillovers with other channels, predominantly market links followed by R&D co-operations and informal networks. To analyse these complementarities between different knowledge channels in more detail is a key issue for future research.

Also, the findings as regards the combinations of geographic scales challenge some of the arguments made in the literature. The results indicate that the international level plays a highly important role for sourcing knowledge from clients and suppliers. Consistent with this finding, also buying machinery and equipment is most important on the international level. Furthermore, the international level is very relevant for most spillovers (except recruitment of skilled workers). The regional and national levels in contrast are considered more important for R&D co-operations. Our results thus clearly challenge the local buzz and global pipelines argument. Our findings, however, also challenge to some extent the knowledge base concept and its assumption that knowledge sourcing in synthetic industries is to a considerable extent spatially bounded. Our analyses, in contrast, strongly point to a high importance of international knowledge linkages, particularly with clients and suppliers. Lastly, the RIS literature suggests that knowledge circulation at the regional level is of high importance. In the investigated case, the relevance of the region is confined to a few sources and channels.

The results can, however, be understood considering simultaneously the industry's knowledge base and value chain, as well as RIS characteristics. The central role of clients was confirmed, as expected for an industry with a synthetic knowledge base. The high importance of international linkages in this regard can be explained by the fact that the main clients of Austria's automotive firms are located beyond the country's borders. The importance of regional and national universities and R&D institutes relates to the strong, institutionally thick RISs in the three investigated regions. Hence, the patterns of knowledge sourcing combinations result from the specific industrial context, the knowledge bases and the configurations of RISs.

Our results have clear implications for innovation policy. The findings presented in this article provoke to take a critical stance on policies that foster knowledge sourcing activities from particular sources, channels and spatial scales only. Exclusive promotion of regional knowledge circulation, for instance, might be misleading, given the high importance of global knowledge sourcing activities for innovation. The same holds true for policies that focus only on single knowledge sources (e.g., support for university-industry partnerships) or channels (e.g., promotion of formal networks). Such approaches fall short of grasping the complexity

of knowledge sourcing activities. Promotion of different knowledge channels to various sources at different spatial scales appears to be a more promising policy approach. Particularly, the specific regional configurations as regards industry, knowledge base and RIS need to be taken into consideration. This conclusion is in line with recent work on new directions of innovation policy (see, for instance, Asheim, et al., 2011; Dahlström & James, 2012; Isaksen & Nilsson, 2012; Tödtling & Grillitsch, 2012).

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Table 1. Dimensions of knowledge sourcing activities and their conceptual treatment

	Sources	Geography	Channels
Local buzz and global pipelines	Not explicitly mentioned	Complementarity between local and global knowledge flows	Distinction between informal (buzz) and formal (pipelines) channels of knowledge transfer
Knowledge Bases	Dominant sources: i) analytical: R&D facilities ii) synthetic: clients and suppliers iii) symbolic: project dependent	Geographical pattern explained by dominant knowledge types: i) analytical: codified/know-why: global ii) synthetic: tacit/know-how: geographic proximity plays a bigger role than for the analytic but smaller role than for the symbolic knowledge bases iii) symbolic: tacit/highly contextual/know-who: local	Dominant channels: i) analytical: R&D co-operations ii) synthetic: learning-by interacting through formal and informal networks with clients and suppliers iii) symbolic: project groups
STI/DUI modes of innovation	Dominant sources: i) STI: R&D facilities ii) DUI: clients and suppliers	Geographical pattern explained by dominant knowledge types: i) STI: codified/know-why: global ii) DUI: tacit/know-how/know-who: local	Description of learning mechanisms rather than channels: i) STI: scientific methods and application of results in innovations ii) DUI: learning by doing and using
Regional Innovation Systems	Focus on linkages within and between knowledge exploration and exploitation subsystems, a variety of sources is considered important	Regional dimension dominant while the importance of extra-regional linkages is acknowledged; recent work links the geographical pattern of knowledge links to the characteristics of the RIS (e.g. thick RIS more regional than thin RIS)	Interactive channels are considered most important

Table 2. Survey and response rate

Regions	Total population		Completed questionnaires		Response rate in %
	Number of firms	Share of firms in %	Number of firms	Share of firms in %	
Upper Austria	146	38	77	43	53
Styria	110	28	49	27	45
Vienna and Lower Austria	131	34	55	30	42
Total	387	100	181	100	47

Table 3. Sample characteristics, N=181

Firm characteristics	Share of firms in %
Functions	
Sales	58.6
Production	90.6
Research and development	61.3
Administration	44.2
Modes of production	
Job production	40.3
Small batch production	61.3
Large batch production	53.6
Mass production	19.3
Regular innovation activities (2004-2006)	
Basic research	13.4
Applied research	25.1
Product development	73.7
Process development	65.4
Innovation outputs (2004-2006)	
Product innovations	82.9
Improvement of products	73.0
Products new to the firm	48.9
Products new to the market	53.9
Process innovations	81.8
Improvements of processes	71.7
Processes new to the firm	42.2
Processes new to the sector	28.3
Size of firms (Number of employees)	
Small (1-49)	21.1
Medium (50-249)	40.6
Large (more than 250)	38.3
Location of headquarters of groups	
Not part of a group	36.5
In the region	30.9
In Austria	9.4
In Europe	13.8
Global	9.4

Table 4. Important knowledge sources, N=181

Sources	Share of firms in %	
Clients	94	(67)
Competitors	52	(9)
Suppliers	51	(12)
Universities	49	(11)
R&D institutes	46	(13)
Engineering and consulting firms	31	(6)
Firms from other sectors	18	(5)

Note: Numbers in brackets: Share of firms rating the respective source as "very important"

Table 5. Combinations of knowledge sources, N=181

Sources	Share of firms in %
All sources	18.8
Clients, scientific knowledge providers & competitors	14.9
Clients, scientific knowledge providers & suppliers	12.7
Clients, competitors	11.6
Clients, suppliers	11.0
Clients & scientific knowledge providers	10.5
Clients only	8.3
Clients, suppliers & competitors	6.1
Other/no sources indicated	2.2
Scientific knowledge providers only	1.1
Suppliers only	1.1
Scientific knowledge providers & suppliers	1.1
Scientific knowledge providers & competitors	0.6
Total	100.0

Table 6. Important knowledge channels, N=178

Channels	Share of firms in %	
Literature, patents	75	(21)
Fairs, seminars, congresses, workshops	74	(18)
Observation of other firms	68	(15)
Buying machines & equipment	63	(29)
Recruitment of skilled workers	57	(17)
R&D co-operations	52	(19)
Private contacts	43	(9)
Consulting/engineering contracts	41	(8)
Research contracts	37	(4)
Participation in working groups	32	(3)
Buying licences	12	(4)

Note: Numbers in brackets: Share of firms rating the respective channel as "very important"

Table 7. Combinations of knowledge channels, N=178

Channels	Share of firms in %
All channels	32.6
Spillovers & market	17.4
Spillovers, market & informal networks	14.0
Spillovers, market & R&D co-operations	12.4
Spillovers only	7.9
Spillovers & informal networks	3.4
Spillovers & R&D co-operations	2.8
No channels indicated	2.2
Market only	2.2
Spillovers, R&D co-operations & informal networks	1.7
Market & R&D co-operations	1.1
Market, R&D co-operations & informal networks	1.1
R&D co-operations only	0.6
Market & informal networks	0.6
Total	100.0

Table 8. Geographic combinations of knowledge sources, N=181

Spatial levels	Share of firms in %
All levels	40
International & national	21
International only	20
International & regional	9
Regional & national	5
Regional only	3
No spatial level indicated	2
Total	100

Table 9. Spatial distribution of knowledge sources, N=178

	Share of firms in % with links		
Knowledge Sources	regionally	nationally	internationally
Clients	22	34	77
Competitors	7	8	46
Suppliers	13	17	38
Universities	30	32	18
R&D Institutes	27	27	18
Engineering and consulting Firms	16	13	17
Firms from other sectors	6	8	15

Table 10. Geographic combinations of knowledge channels, N=178

Spatial levels	Share of firms in %
All levels	66
International only	11
International & regional	10
International & national	7
No spatial level indicated	4
Regional only	2
Regional & national	1
Total	100

Table 11. Spatial distribution of knowledge channels, N=178

	Share of firms in % with links		
Channels	regionally	nationally	internationally
Fairs, seminars, congresses, workshops	24	29	65
Literature, patents	22	26	63
Observation of other firms	16	21	60
Buying machines & equipment	17	22	56
R&D co-operations	27	24	19
Recruitment of skilled workers	43	25	19
Consulting/engineering contracts	23	15	19
Research contracts	22	26	18
Private contacts	31	27	17
Participation in working groups	15	17	17
Buying licences	4	3	8

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